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CONTENTS OF VOLUME XXVI.

PROCEEDINGS

OF THE

BOSTON SOCIETY OF NATURAL HISTORY.

TAKEN FROM THE SOCIETY'S RECORDS.

GENERAL MEETING, NOVEMBER 2, 1892.

President W. H. NILES in the chair. Eighty-four persons present.

The President announced that the Society had lately received a gift of $5,000 from Miss B. L. Randall, executrix of the late John Witt Randall, and that the income of the fund established therefrom would be devoted to the increase of the library.

It was announced that the following Corporate Members had been elected by the Council: Messrs. A W. Grabau, L. S. Griswold, John Lowell, W. H. Patton, M. A. Reed, C. C. Rounds, H. F. Sears, and Miss Frances Zirngiebel.

The following papers were read by title: "Physical geography of Texas," by R. S. Tarr; "Notes on the transformation of the higher Hymenoptera," by A. S. Packard.

Prof. George L. Goodale spoke of certain aspects of the vegetation of New Zealand.

GENERAL MEETING, NOVEMBER 16, 1892.

President W. H. NILES in the chair. Ninety-five persons present.

The following paper was read:—

THE ORIGIN OF DRUMLINS.

BY WARREN UPHAM.

Contents.

1. VARIETIES OF DRUMLINS AND THEIR AREAL DISTRIBUTION.

Among the phases of the glacial and modified drift, comprising together all the deposits formed by the ice-sheet and the water of its melting, no other is so fully and distinctly developed in Boston and its neighborhood as the drumlins. These drift hills therefore have been brought often before the attention of our Society during the past twenty-two years by Professors Shaler[1], Wright[2], Hitchcock[3], Davis[4], and Crosby[5], and by the present writer.[6] More recently, during the years 1890 to 1892, the drumlins of the entire State of Massachusetts have been mapped and carefully studied by Mr. George H. Barton, under the direction of Prof. N. S. Shaler, for the United States Geological Survey. Their total number is found to be about 1,500, counting the separate rounded summits

[1] Proceedings Boston soc. nat. hist., vol. 13, 1870, p. 196-204.

[2] Ibid., vol. 19, 1876, p. 58; vol. 20, 1879, p. 217. See also The Ice Age in North America, 1889, chapter 11.

[3] Proceedings Boston soc. nat. hist., vol. 19, 1876, p. 63-67.

[4] Ibid., vol. 22, 1882, p. 34, 40-42. See also Amer. journ. sci., ser. 3, vol. 28, Dec., 1884, p. 407-416.

[5] Proceedings Boston soc. nat. hist., vol. 25, 1890, p. 115-140.

[6] Ibid., vol. 20, 1879, p. 220-234; vol. 24, 1888, p. 127-141; and vol. 24, 1889, p. 228-242. In the last of these papers, sections of the drumlins named Third and Fourth Cliffs in Scituate, Mass., of drumlins forming islands in Boston Harbor, and of Central Hill in Somerville, are described; and many other papers relating to drumlins elsewhere in this country and in Europe are cited.

of compound drumlin aggregations, where two or three of these hills, or sometimes more, are merged together at their bases.

Drumlins consist, at least superficially and in most cases throughout their entire mass, of till or boulder-clay, being unstratified clay, sand, gravel, and boulders, mingled indiscriminately together, which therefore must be attributed to deposition by ice without modification by the assorting and stratifying action of currents of water. They have usually an oval form, with smoothly rounded top and steep slopes, especially at the sides, from which features Prof. C. H. Hitchcock in 1876 named them *lenticular hills*, the first distinctive term applied to these drift accumulations in this country. Subsequently the name drumlins, used by M. H. Close ten years earlier for similar hills and ridges of till in Ireland, has come also into common use here.

Oval or elliptical forms of drumlins prevail, with rare exceptions, in New Hampshire, Massachusetts, and Connecticut. In some other districts, as in central New York, these hills vary from the oval type to prolonged ridges, running nearly straight several miles; and in eastern Wisconsin, as described by Chamberlin, they are prevailingly circular and dome-shaped on some areas, being therefore called *mammillary hills*, while in other localities they occur mainly as long parallel ridges. Wherever drumlins are found, their longer axes trend in parallelism with the courses of the glacial striae and transportation of boulders, that is, with the current of the ice-sheet. Glacialists are agreed that this relationship and the very regular and smooth contour of the drumlins resulted from the moulding action of the overriding ice, to which masses thus elongated opposed the least resistance.

In the areas of their greatest development the drumlins range in height from 25 or 50 feet up to 200 feet or rarely more, and proportionally in length from an eighth of a mile to one mile, or, in tracts where they become long ridges, two to three miles or more. The slopes of their ends are gentle or moderately steep, having from 5 to 20 feet of ascent in a distance of a hundred feet; but the steeper ascent of their sides varies usually from 15 to 30 feet in the same distance. Instead of amassing the till in such prominent accumulations, we should expect that the ice-sheet would tend constantly to wear away the hilltops and leave thick deposits of subglacial drift only in depressions of the country and on low or nearly level land.

The till forming the drumlins invariably exhibits the characteristic features of subglacial till or ground moraine, excepting its superficial portion which was englacial and superglacial when the ice-sheet melted away.[1] Many boulders, which are commonly strewn plentifully on the surface of the drumlins, appear to have fallen upon them from the receding ice-sheet, together with a stratum of the till that varies usually from one foot to a few feet in depth near Boston, but is sometimes from 10 to 15 feet thick on the tops and flanks of drumlins in New Hampshire. This upper part of the till is comparatively soft and easy to dig, while its main portion below is so compact that it must be picked and is far more expensive in excavating. The probable cause of the contrast in hardness was the pressure of the ice-sheet upon the lower till during its accumulation, while the upper till was contained in the ice and dropped loosely at its melting. Occasionally a thin layer of sand or gravel lies between the englacial and subglacial till, as on the top of the drumlin named Convent Hill in Somerville, where the upper 3 feet of the till, forming the surface, are underlain along an observed distance of several rods by a bed of sand from 1 to 3 feet thick.

Subglacial till is further distinguished from that which was finally dropped from the departing ice by its smaller rock fragments, which are mostly less than two feet in diameter, and sometimes consist only of pebbles, cobbles, and small boulders not exceeding half this size, though often it also contains large boulders; by the glacially worn faces of many of these stones, which are frequently marked with striae; and by traces of a peculiarly bedded structure, in parallelism with the surface. The last feature is especially characteristic of the till in drumlins, excepting its upper few feet. Although boulders, gravel, sand, and clay are thoroughly commingled, the deposit is imperfectly laminated and tends to separate and crumble into thin flakes. This is frequently noticeable in a fresh excavation, but is most distinctly seen after a few weeks of exposure. It shows that the ice in its passage added new material to the surface of the ground moraine, which generally lay undisturbed beneath.

To a depth that commonly varies from 5 to 10 feet on low or

[1] Inequality of distribution of the englacial drift. Bulletin G. S. A., vol. 3, 1891, p. 134–148. Criteria of englacial and subglacial drift. Amer. geol., vol. 8, Dec. 1891, p. 376–385.

moderately sloping tracts, but is often from 15 to 20 feet or more on the drumlins, the color of the till is yellowish gray or buff, while at greater depths it is a darker and bluish gray. This difference in color is due to progressive weathering, the influence of air and water upon the iron contained in the till having changed it in the upper part from protoxide combinations to the hydrous sesquioxide. On low tracts the weathering of the till is often limited to its comparatively loose englacial portion, but it has generally extended beyond into the subglacial till of the drumlins.

Most instructive variations from the usual constitution of the drumlins are presented where anticlinally stratified beds of gravel, sand, and clay or fine silt, form their inner part, reaching in a dome-shaped accumulation from the base upward to comprise sometimes the greater part of the section, with a deposit of till, which may be from a few feet to 25 feet or more in thickness, spread over these beds so as to form the entire surface. Among many sections of drumlins observed by me in New England, the only examples of this structure are Third and Fourth Cliffs, partially eroded drumlins in Scituate, Mass., on the shore of Massachusetts Bay. These rounded, low hills, rising respectively about 70 and 60 feet above the sea, consist of till upon their whole surface and to a depth that varies from 15 to 25 feet and more, but below include beds of modified drift that attain in Third Cliff a thickness of at least from 30 to 48 feet, reaching to the boulder-strewn shore, and in Fourth Cliff a thickness of from 10 to 20 feet, being seen there to be underlain by till and to be also in part interbedded with it.

Generally throughout drift-bearing areas the till, excepting where it is accumulated in the hills and knolls of the terminal moraines, has a comparatively low and level or moderately undulating surface. But on certain tracts a large part of the till is exceptionally amassed in the drumlins, which stand up very conspicuously as high hills, sometimes occurring plentifully with irregular arrangement in groups or belts which may extend from 20 to 50 miles or more and often have their greatest length in parallelism with the course of the terminal moraines. Elsewhere drumlins are sparingly scattered here and there with intervals of several miles between them, this being often observed on the borders of their tracts of greatest abundance; and rarely a single typical drumlin, as Pigeon Hill on Cape Ann, may be separated many miles from any other like accumulation of till.

It would be expected that the abundance or absence of drumlins must be determined, or at least influenced, by the varying contour and diversity in lithologic characters of the bed rocks; but I have been unable to discover this relation or dependence, if any exists. In southern New Hampshire, and southward to the neighborhood of Boston, the drumlins are finely developed on some portions of the low land near the coast, being spread over areas which would otherwise be nearly level; but at many places inland they are equally abundant among high irregular hills of rock. They seem as likely to be found on one side as another of any mountain or prominent hill range; and the altitudes at which they occur vary from the level of the sea to 1,500 feet above it on the height of land between the Merrimack and Connecticut Rivers. Interspersed with the tracts of plentiful drumlins are other tracts which have none. If their distribution has been mainly independent of the differences in topography and the limits of various rock formations, as seems to be true, we are brought to the alternative that it probably resulted from movements of the ice-sheet and the conditions of its erosion, transportation, and deposition of the drift.

Besides the frequent arrangement of these hills and ridges of till in groups and somewhat definite belts, which are from a few miles to 10 or 20 miles wide, with intervening belts or irregular areas destitute of drumlins, a still more noteworthy feature of their geographic distribution is found in their occurring thus upon some extensive districts, while they are utterly wanting on larger portions of the great glaciated areas of North America and Europe. On this continent the districts where they are found range from southwestern New Brunswick through the southern parts of Maine and New Hampshire, and through Massachusetts and Connecticut, to central and western New York; and farther toward the west, drumlins are encountered again in great abundance and variety in the eastern part of Wisconsin, extending also into the northern peninsula of Michigan, beyond which they have been reported only as islands of Lake Winnipegosis in northwestern Manitoba. It seems very probable that all these areas were uncovered contemporaneously from the ice-sheet during the same general stage of its final recession.

2. OBJECTIONS TO FORMER THEORIES OF THE ORIGIN OF DRUMLINS.

Several theories of the way in which the ice-sheet produced the drumlins have been suggested. The earliest was by Shaler in 1870, who supposed these hills in the vicinity of Boston to be remnants spared by the fluviatile and tidal erosion of a once continuous sheet of drift, which had been contained in a glacier that descended the Charles River valley. His later view is similar, but attributes the very thick drift sheet of his hypothesis to deposition during the earlier of two epochs of glaciation, and its erosion partly to sea and river action during an interglacial epoch, but mainly, for the peculiar sculpture of the drumlins, to excavation and removal of the drift from all the intervening areas by the later glaciation. To accord with this view, however, the terminal moraines of the later ice-sheet must vastly exceed their very moderate observed volume. Another objection, pointed out by Salisbury[1], is that the drumlins appear to be composed wholly of the newer drift.

Hitchcock and Wright have thought the drumlins to be perhaps the material of terminal moraines swept over and massed in these peculiar forms by subsequent farther advances of the ice-sheet. If this view were true, the till of the drumlins could not have its nearly uniform character, but would contain here and there remarkable aggregations of boulders, and frequent irregular enclosures of sand and gravel would be found, representing the kame deposits and lenticular beds of modified drift which so commonly make up considerable parts of the terminal moraines. Salisbury remarks that neither the distribution nor the composition of the drumlins seems to favor this hypothesis, and he therefore believes that they were built up beneath the ice, not being fashioned from hills overridden by it.

Mr. Clarence King and Prof. J. D. Dana have conjectured that the drumlins, at least in some cases, were made by superglacial streams, charged with drift, pouring through crevasses or a moulin to the land surface, there depositing their drift, which afterward by the onflow of the ice would be subjected to its pressure and sculpturing. This explanation lies under similar objections to those of the last.

Kinahan and Close in Ireland, Prof. James Geikie in Scotland,

[1] Geol. surv. of N. J. Ann. rept. for 1891, p. 71-75.

and Davis and Salisbury in this country, look on the drumlins as analogous to the sand bars of streams. Professor Davis writes:—

"In view of the irregularity of the surface on which the ice-sheet moved, and of the greater weakness of some rocks than others, we must suppose an irregular velocity in the motion of the ice and an unequal distribution of the rubbish beneath it. If the faster motion at one place causes an excess of erosion there, the slower motion at another place may bring about an excess of deposition. This difference of action is known to prevail between the central and marginal parts of glaciated areas; and the local accumulation of drumlins in an intermediate region gives a smaller example of these two parts played by the ice. If the causes of the irregular motion of the ice lie in the general form of the country, the location of faster and slower currents will be relatively permanent; the districts of faster currents would be found where the greatest volume of ice is allowed to pass, and some of the points of retardation may be the seats of long continued drumlin growth."[1]

For accordance with this theory, the areas bearing drumlins should be determined chiefly by the topography and rock formations, which, however, seem to have exerted little influence. Furthermore, the rapid accumulation of the drumlins, shown by my last paper on this subject before this Society to have been in some cases at the rate of from one to six feet or more of till yearly added to their surface, appears inconsistent with the belief that they were mostly supplied from drift immediately before eroded from the land surface and transported by subglacial dragging to its place in these drift hills.

3. PROBABLE ACCUMULATION OF THE DRUMLINS FROM ENGLACIAL DRIFT.

The origin of the drumlins may be better understood, or at least to the writer it seems more intelligible, if we inquire how the drift which had been englacial until the time of departure of the ice would be deposited.

It is evident that the ice-sheet in its passage over a mountain-

[1]Amer. journ. sci., ser. 3, vol. 28, Dec., 1884, p. 415.

ous or hilly country must gather much drift into its lower part, to as great height as the altitude of the mountains and hills, by grinding off and plucking away detritus and blocks of rock from these elevations, thence carrying them forward enclosed within the ice many hundreds of feet, and in the lee of the White, Green, and Adirondack Mountains even thousands of feet, above the ground. But it has seemed to some geologists difficult to account for the transportation of much drift into the ice from moderately undulating or plain districts, such as make the greater part of the drift-bearing areas of our continent and of Europe. On these nearly flat tracts, however, I find at localities in Minnesota and Manitoba good proofs, as they seem to me, that the thickness of the englacial drift was sometimes as much as forty feet near the ice-border where it was amassing prominent terminal moraines, and on lines or belts where confluent ice currents met from broad regions on each side.[1] Similarly in England, according to the observations of Mr. G. W. Lamplugh, a confluent ice-sheet flowing from Scandinavia and Scotland was pushed up on the Yorkshire coast, bringing much englacial drift, with marine shells, which it had eroded and gathered up from the shallow and almost level basin occupied before the Ice age and again afterward by the North Sea.[2]

The manner in which the ice gathered drift into its basal portion from any plain tract seems to me explainable by a consideration of the currents of outflow toward its border. In the central area of the ice-sheet the currents of its upper and lower portions probably moved outward with nearly equal rates, the upper movement being slightly faster than at the base. Upon a belt extending many miles back from the margin, however, where the slope of the ice surface had more descent, the upper currents of the ice, unsupported on the outer side, would move much faster than its lower currents which were impeded by friction on the land. There would be accordingly within this belt a strong tendency of the ice to flow outward with somewhat curved currents, tending first to carry the onwardly moving drift gradually upward into the ice-sheet, and later to bear it downward and

[1] Geol. and nat. hist. surv. Minn. Ninth ann. rept., for 1880, p. 322–326. Final rept., vol. 1, 1884, p. 603, 604. Geol. and nat. hist. surv. Can. Ann. rept., new ser., vol. 4, for 1888–89, p. 38–40 E.

[2] Quart. journ. geol. soc. Lond., vol. 47, 1891, p. 384–431, with maps and sections.

deposit it partly beneath the edge of the ice and partly along the ice boundary.

Whenever the warm climate terminating the Glacial period extended unchecked through many years, the depth of the ablation or superficial melting of the outer part of the ice-sheet was probably not less than from 15 to 25 feet each summer, as has been observed on the Muir glacier in Alaska[1] and on the Mer de Glace in Switzerland.[2] At such rates of melting any district enveloped by ice from 2,000 to 4,000 feet thick, as was true of the central portions of New England and doubtless also of a broad belt thence west to the Laurentian lakes and to Minnesota and southern Manitoba, would be uncovered in one or two centuries, and the recession of the glacial boundary would average probably a half mile or more yearly.

During any long series of years when the ice-sheet was being thus rapidly melted, its outer portion to a distance of probably twenty miles from its boundary, being reduced by ablation to a thickness ranging from 100 feet and less upward to 1,000 feet, would bear on its surface, especially in the valleys and hydrographic basins of its melting, much drift which had been before contained in the higher part of the ice. Only scanty englacial drift, mainly consisting of boulders borne away from hills and mountains, appears to have existed at altitudes exceeding 1,000 or 1,500 feet; but all the lower ice probably contained an increasing proportion of detritus and boulders which had been brought into it from below by the upward movements due to faster flow of the central and upper glacial currents than of those retarded by friction on the ground. The thinned border of the ice-sheet upon the belt having a remaining thickness of less than 1,000 feet would therefore become covered with drift, as Russell has described the borders of the Malaspina glacier or ice-sheet, which stretches from the Mt. St. Elias range to the ocean.[3]

At many times the general recession of the ice-sheet was temporarily interrupted. The return of a prevailingly cold climate for several decades of years, or occasionally, as we may suppose,

[1] H. F. Reid, in Nat. geogr. mag., vol. 4, March, 1892, p. 31, 38.

[2] Prestwich's Geology, vol. 1, p. 176.

[3] Nat. geogr. mag., vol. 3, 1891, p. 53–203, with 19 plates and maps. Amer. journ. sci., ser. 3, vol. 43, March, 1892, p. 169–182, with map. Amer. geol., vol. 8, Dec., 1891, p. 384.

for a century or more, brought increased snowfall, which sufficed to hold the ice boundary nearly stationary, perhaps frequently first having pushed it again a considerable distance forward. The thick ice lying far back from the border may then have flowed over its previously thin and drift-covered outer belt, aiding with the new snowfall to envelop the once superglacial drift stratum within the ice-sheet. These halts or re-advances, if the front of the ice had a nearly constant position during several years, became marked by terminal moraines, of which I have mapped a series of eleven in consecutive order from south to north in Minnesota, North Dakota, and Manitoba, while Mr. Frank Leverett has traced a still larger number through Illinois, Indiana, and Ohio. With the increased thickness and steeper gradient of the outer belt of the ice-sheet while the recession of its boundary was slackened, wholly stopped, or changed to a re-advance, due mainly to very abundant snowfalls, much drift which had been formerly exposed on the ice surface would become again englacial, so that a stratum of drift several feet thick might be enclosed in the ice at an altitude increasing inward from less than 50 feet to 500 feet or more.

The upper current of the thickened ice above the englacial bed of drift would move faster than that drift, which in like manner would outstrip the lower current of the ice in contact with the ground. Close to the glacial boundary, whether it halted and even re-advanced or merely its retreat was much slackened but did not entirely cease, which last seems probably to have been the case with the drumlin areas of Massachusetts and New Hampshire, the upper part of the ice must have descended over the lower part. This differential and shearing movement, as I think, gathered the stratum of englacial drift into the great lenticular masses or sometimes longer ridges of the drumlins, thinly underlain by ice and overridden by the upper ice flowing downward to the boundary and bringing with it the formerly higher part of the drift stratum to be added to these growing drift accumulations. The courses of the glacial currents and their convergencies to the places occupied by the drumlins were apparently not determined so much by the topography of the underlying land as by the contour of the ice surface, which under its ablation had become sculptured into valleys, hills, ridges, and peaks, the isolation of the elevations by deep intervening hollows being doubtless most conspicuous near the ice-margin.

In New England, on account of the absence or extreme rareness of any beds of modified drift which give evidence of having been covered by a re-advance of the ice, the till of the drumlins, according to this view, appears to have been collected into its present masses in the basal part of the ice-sheet, while a moderate thickness, probably seldom more than 50 or 100 feet, of ice lay beneath. Over the drumlins a somewhat greater thickness, perhaps varying from 200 to 500 or 1,000 feet, of ice formed largely from the snowfalls of recent years or the immediately preceding century or more, with probably much addition from the thick inner part of the ice-sheet, containing from whichever source little or no drift, passed and molded these hills in their smoothly oval or round or elongated forms.

It is thus readily seen why the amount of finally englacial drift upon the surface of drumlins is usually less than on intervening tracts of low ground and on those parts of the drift-bearing area from which the ice-sheet was more rapidly melted away.

We can also understand why these accumulations are so frequently found capping the top of low hills of the bed rocks, since these projected through the ice that lay beneath the superglacial and afterward again englacial drift stratum and so were obstacles to favor an aggregation of that drift, either as a complete drumlin resting on the hill of rock, or as a lenticular slope of till, of which abundant examples are found in New Hampshire, collected on the stoss or the lee side of the rock hill, and occasionally in slopes of this form covering both these most exposed and most sheltered sides of the hill thickly and its intervening flanks thinly, with visible outcrop of the rock only on its summit.

Powderhorn Hill in Chelsea, one of the largest drumlins near Boston, rising about 200 feet above its base, which is near the sea level, and having an exceptionally elongated form, with a length of three quarters of a mile and one fourth as great width, affords evidence that a slight thickness of ice remained beneath it when it was accumulated. Extensive excavations, from 20 to 40 feet deep, in each end of this drumlin consist wholly of till, with no trace of any bed or seam of stratified drift. In one of these sections about 30 feet high on the north side of its southeastern end, I observed a nearly vertical irregular course of fracture, from one to six inches wide, filled with sand and fine gravel brought by percolating water, where this long hill had suffered a slight disloca

tion in sinking as the underlying ice melted. Such fractures extending deeply into this hill were also found in the construction of the reservoir on its top, which gave much trouble by leaking, until the bottom was made impervious with cement. The till where not so fractured is water-tight, and numerous reservoirs on other drumlins near Boston have been free from this difficulty. The narrowness of Powderhorn Hill, in proportion to its length, probably caused it to sink more unequally than most of the drumlins in this district.

On some other areas, and perhaps more commonly, drumlins may have been formed from the englacial stratum of drift during a time of re-advance of the ice-sheet, carrying the drift forward so that it would be accumulated on a land surface. This appears to have been the case in central New York, where Prof. W. M. Davis finds that the sections of drumlins frequently show stratified gravel and sand underlying the till, and that often the relationship of these formations is such as to prove that the stratified beds were somewhat eroded before the deposition of the till. But the absence of such sections in Massachusetts and generally in New England makes it probable, as stated, that here the recession of the ice was continued, though with a much diminished rate, while the drumlins were being amassed.

4. REVIEW OF OBJECTIONS TO THIS EXPLANATION.

At first sight, this explanation of the accumulation of the drumlins appears to be opposed by two conspicuous objections, which must be answered. The first is the local derivation of much of their material. Where the peculiarities and restricted limits of the adjacent rock formations on the north permit an approximate determination of the distances of transportation of the drift forming the drumlins, it is found that a large part, sometimes more than half, has been carried only a few miles. It seems surprising that local material should constitute so important an element of the drift contained within the ice at considerable heights, until we consider how fast it would be uplifted by even a very slight upward inclination of the basal current of the ice. If the drift eroded from any place was carried up with an average ascent of only one degree, it would rise within one mile to an altitude of 92 feet above the ground, and within two to three miles would be

as high as the tops of the most prominent drumlins. Currents ascending at this rate, or even two or three degrees or more, may very probably have existed in the lowest part of the ice-sheet, on account of the acceleration of its upper currents, within distances from 20 to 50 miles or more back from its boundary. By these currents much drift eroded from the land surface would be gradually incorporated in the comparatively sluggish lower part of the ice, reaching altitudes from 100 to 1,000 feet above the ground within a few miles from its sources.

When the boundary receded, the upper currents of the outer belt of the ice, upon a width of probably ten miles, would pour down toward the open land, causing the deposition of much subglacial till; and whenever a stratum of the englacial drift became covered with much new ice, it would probably be aggregated englacially or altogether subglacially in drumlins. The drift that had been eroded and lifted into the lower part of the ice during many centuries might thus be rapidly accumulated in the drumlins during only a very small fraction of the time that had been required for its being stored up in the ice. Through such processes I can better understand the origin of these prominent drift hills, than by any method that I am able to imagine for nearly contemporaneous erosion, subglacial transportation, and deposition of their till. Moreover, I find great difficulty in forming a conception of convergent basal currents powerful enough, in spite of their friction on the land, to amass these hills; but the inequalities of contour of the outer belt of the ice, as irregularly thinned by ablation, may well have produced upper and central currents of sufficient energy to sweep the englacial drift stratum into irregularly grouped and scattered or even solitary drumlins, when new ice and snowfields added a considerable depth over all the previous drift-covered surface of the ice-sheet.

The second objection alluded to arises from the abundance or frequency of glaciated stones and boulders in the till of the drumlins, and from its compactness, flaky lamination, and other features which prove it to be subglacial till or ground moraine. If this drift was englacial during a considerable time and became amassed in these hills beneath only a few hundreds of feet of ice, could it present so impressive characteristics of subglacial accumulation under heavy pressure? To this question we must reply that the stratum of englacial drift would be subjected to much

wear of its boulders and smaller rock fragments as they were carried forward with shearing and sliding motion to the drumlin accumulations, and that in becoming lodged on the surface of the drumlins or on other and low deposits of subglacial till they would be further striated and planed. The previously englacial drift in being so transported and deposited would acquire all the marks of ice-wear which the till of the drumlins exhibits, and the pressure of from 500 to 1,000 feet, more or less, of solid ice flowing downward across it would seem adequate to produce its very hard and compact condition. We are thus able, as I believe, to account for all the differences between these deposits and the mostly unworn drift which fell loosely on the surface from an englacial or superglacial position when the ice disappeared.

5. COMPARISON WITH TERMINAL MORAINES, KAMES, AND ESKERS.

My study of the glacial Lake Agassiz, under the direction of Prof. T. C. Chamberlin, for the United States Geological Survey and partly for that of Canada, shows that several large terminal moraines, marking pauses or re-advances interrupting the general glacial recession, were accumulated contemporaneously with the existence of that lake, while yet the whole duration of Lake Agassiz was apparently only about a thousand years.[1] The rapidity of formation of the moraines was thus similar to that of the drumlins, and both seem to have been made possible only by the large amount of the englacial drift. The fast retreat of the ice indicates that probably its melting border then had usually a more steeply sloping surface than in its time of greatest extent to the south, and that consequently the rate of motion of the outer part of the ice-sheet was commonly increased during its final melting. Any pause of the retreat for even a few years would therefore form a moraine, though the outer belt of the ice may have been generally too steep to expose much superglacial drift. But during some stages of the recession we may conclude that considerable tracts of the ice-border were so thinned by ablation that much englacial drift became superglacial, with the result that when again a colder climate brought a temporary thickening

[1] Geol. and nat. hist. surv. Can. Ann. rept., new. ser., vol. 4, for 1888–89, p. 50, 51 E. Amer. geol., vol. 7, April, 1891, p. 224–226.

of this marginal ice the previously superglacial stratum of drift was chiefly amassed in drumlins. The known drumlin areas of New Brunswick and New England, New York, Wisconsin, and Manitoba, would therefore be expected to belong to the same stages of the closing part of the Ice age. This would imply what seems from other reasons not improbable, that the outermost moraines in the States east of Ohio and on the east side of the driftless area in Wisconsin correspond to some of the inner and late moraines in the greater part of the region of the Laurentian lakes and the upper Mississippi, as perhaps the exceptionally massive Leaf Hills, Itasca, and Mesabi moraines, which are the ninth, tenth, and eleventh of the series in Minnesota.

Again, in confirmation of the view that much drift was contained in the lower part of the ice-sheet, my studies of the very massive kame deposits forming the greater part of the outermost terminal moraine on Long Island eastward from Roslyn, of the large kame called the Devil's Heart, rising in a somewhat conical hill 175 feet above the adjoining country south of Devil's Lake in North Dakota, and of the esker named Bird's Hill, seven miles northeast of Winnipeg, seem to me to demonstrate, beyond all doubt, that their material, and probably likewise that of kames and eskers generally, was supplied by superglacial streams from plentiful englacial drift, and could not have been brought from drift beneath the ice by subglacial drainage.

In conclusion, I deem it a duty to state that this reference of the drumlins, terminal moraines, kames, and eskers, to rapid accumulation from previously englacial drift during the departure of the ice, seems to me better accordant with the view that the Ice age comprised only one great epoch of glaciation, attended by oscillations of the ice-border, than with the alternative view, hitherto held by me during the past thirteen years, as by most American glacialists, which supposes the ice-sheets to have been at least once and perhaps several times almost entirely melted away, afterward being restored by recurrent glacial epochs.[1] The drumlins, like the terminal moraines, are effects of secular vicissitudes of climate on the border of the departing ice-sheet, which I think to have owed its existence to great altitude of the land at the beginning of the Glacial period, to have been attended when

[1] See the recent article by Prof. G. F. Wright, Unity of the Glacial epoch, Amer. journ. sci., ser. 3, vol. 44, Nov. 1892, p. 351–373.

at its maximum extension and volume by depression of the land on which it lay, and to have witnessed, during the retreat and removal of its load, a progressive re-elevation of the same area to its present height.

Prof. W. M. Davis said: The most interesting question for the consideration of our members here present, most of whom are not actively engaged in geological study, is not so much how drumlins are made, but why should there be any difference of opinion regarding their origin in the face of a carefully argued explanation, such as has just been presented by Mr. Upham.

In geometrical analysis, demonstrations have held true for thousands of years, because they are founded on accepted axioms and reached by a thoroughly logical sequence of deductions, from no one of which there is any alternative escape. In geological analysis, the postulates that serve us for axioms probably have somewhat different forms in different minds; the sequence of argument by which conclusions are sought contains many alternative possibilities, because it involves many matters not fully demonstrable and therefore susceptible of various interpretations. Geological arguments lead only to probable conclusions, and their safety must be measured not only by the logical sequence of the steps, on every one of which there might be several other turns taken besides the one that is followed, but also as by the degree of accordance found between the consequences reached through the argument and the facts with which they may be confronted. Beginning by agreeing with Mr. Upham in our general conception of the former presence of an extended ice-sheet over the drift region of northern North America, we continue to agree essentially regarding the faster motion of the surface than of the bottom layers of the ice; we then differ more or less regarding the effectiveness of an upward movement resulting from the differential velocities of the ice, by means of which the subglacial drift becomes englacial in greater or less amounts, and to greater or less heights; we consequently differ still more regarding the amount of drift possibly accumulated on the surface of the ice during its melting, and regarding the subsequent concentration of this surface drift upon various relatively small parts of the melting ice-sheet. Thus from beginning together, we come

so soon to different estimates of the value of various processes that, from this point onward, our views have little similarity.

We differ again as to the correctness of the inference that can be drawn from the heavily drift-covered margin of the Malaspina glacier of Alaska, as bearing on the condition of the ice surface near the margin of our waning glacial ice-sheet. It seems to me that the supply of the Malaspina glacier from among high mountains, whence it descends along deep narrow valleys, may largely explain the occurrence of a large amount of englacial drift in its middle layers; and that the melting of the upper part of the ice will transform the englacial drift to superglacial drift near the ice margin, without calling on an oblique ascent of the drift from the bottom of the ice. The ice of the Greenland sheet is not so heavily drift-covered near its margin as that of the Alaskan sheet; and while I understand that Mr. Upham explains this peculiarity by contending that the Greenland ice is in a state of increase, instead of decrease, it seems fair on the other hand to explain a considerable share of the difference between the two cases by the absence of high mountains on the Greenland plateau.

Mr. Upham objects to the derivation of our drumlins from the half-wasted moraines of an earlier advance of the ice, because the drumlins do not contain stratified and washed gravels; yet he advances the theory that the superglacial drift, leached out from the ice by surface melting, gathered from a large area of ice surface and concentrated on a smaller one by water action, shall be transformed into drumlins of true till, by a re-advance of the ice. His objection appears to be as applicable in the latter as in the former case. Moreover, as the whole mass of the accumulated and concentrated surface drift must be worked over, part by part, by the ice before it can gain the structure of till, I do not see the usefulness of the concentration, except as affording a possible excessive supply of ready material for ice dragging, of which more below. He maintains further that the newer advance of the ice will climb over the wasting ice of the earlier advance, and that drumlins may therefore often have been formed with a layer of older ice beneath them, and a cover of heavier, thicker ice above them; adducing in evidence of this, first, the theoretical requirements of the process that he describes; second, the occasional occurrence of cracks or crevices in the till of our drumlins, more or less filled in by sand, as if the cracks had been made when the under

ice was melting away so as to allow an unequal settling of the drumlin above it. Such crevices are entirely too exceptional to be used in corroboration of so extremely specialized a condition as an under layer of ice, even if they could not be explained by the unequal settling of less solid drift masses on which, as well as on ice, the drumlin may have been originally accumulated.

It is postulated that drumlins were rapidly accumulated, and hence that some special process of origin such as is now advanced is necessary for their explanation; but here again, the postulate is not universally accepted; and even if it were, the possibility of drumlins being gathered up with comparative rapidity from a drift encumbered district in a re-advance of the ice is not excluded. As a whole, the theory seems to me to be based on special interpretations of phenomena that might be differently interpreted; and I am therefore unable to assert that drumlins were actually formed in this particular way, however possible the way may be.

When we come to the verification of Mr. Upham's theory by the success of its consequences in meeting various facts of observation, we find two classes of difficulty: first, the variety of special consequences that follows from this theory and from no other is small, and hence demonstration by frequent accordance, that is, by excessively probable correctness, is not reached; second, certain special consequences are not clearly confirmed by the facts. I will consider only one other of these, in addition to the examples already mentioned.

In applying the theory to special cases, such as College Hill, a large drumlin a few miles northwest of Boston, I find serious difficulties at every step. College Hill is not more than two miles from the northern boundary of the blue slates of the Boston Basin, yet it contains plentiful fragments of these slates. Now, if the drumlin is formed by the process advocated by Mr. Upham, it must be supposed that the slate fragments were first gathered from ledges at the bottom of the ice; then raised to a considerable height in the ice mass by the inferred differential velocities of flow; next transformed from their englacial state to the condition of superglacial drift by surface melting, whereby the height at which many of them stood within the ice must have been reduced; then washed downward and in a general way southward over the melting ice in the process of surface concentration; again

rubbed over by a new advance of the ice and thus deprived of their more or less angular or water-worn forms and of their more or less stratified arrangement, and given the features of true till; and finally still further reduced in height by the melting away of the lower layer of old ice beneath; and all this inside of a distance of two miles. The present altitude of the summit of College Hill over the lowland to the north of it, whence the slates must have been dragged up, is perhaps two hundred feet; and yet this is only a remnant of the altitude to which the fragments must have been raised in differential motion of the ice, and from which they must have been lowered by melting, washing, rubbing, and settling. The occurrence of numerous large boulders of amygdaloid in the till of a large drumlin in Brookline might be adduced as offering similar difficulties: the ledges of amygdaloid from which the boulders come are not far distant, and it is incredible that they should have been so greatly raised and lowered during so short a horizontal distance of transportation. Further than this, the presence of a large share of fine clay in the till of drumlins seems to me entirely inconsistent with its supposed derivation from washed accumulations of superglacial drift: the clay would be mostly washed away during the slow discovery of the englacial drift as the ice melted.

The process of verification is, therefore, so incomplete at present that I can only regard Mr. Upham's explanation as a suggestion or tentative hypothesis, taking rank along with the several other tentative hypotheses previously invented by others in working on the same problem. Perhaps only one of these hypotheses is shown to be absolutely impossible; certainly not one of them is fully verified as the competent and chief process of drumlin formation.

But if I understand Mr. Upham aright, he is not satisfied that his explanation should take its place simply as a possible process along with other possible processes. He regards all other explanations as entirely inapplicable. This seems to me an unfortunate position in the present stage of our inquiry. Drumlins are accumulations of till, of peculiar thickness and form; it is unsafe to assume that they were all made in a single way. All varieties of processes that contribute to such a result should be welcomed until a demonstrative process of argument reduces their number by exclusion. The particular process that has seemed to me the most plausible, although I am always overcome by its difficulties

when looking at large drumlins in the field, is the one that compares them to sand bars in rivers or to sand dunes on windy deserts. They are, according to this explanation, accumulations of subglacial till at places where more material was brought than could be carried on. The conditions by which such excess of accumulation are determined are so various that it would be as difficult to predict the location of a drumlin among our rugged New England hills as to predict the location of a sand dune on the uneven surface of the Sahara. The excess of subglacial drift may be due to the presence of preglacial soils, to the weakness of the rock foundation, to the presence of earlier drift deposits. The deficiency of transporting power may be due to some inequality of weight or motion of the ice-sheet, not dependent on the immediate locality of the drumlin, but determined by the integration of accelerations and resistances both northward and southward of the locus of accumulation. It seems to me that in our hilly country, where the distribution of the rocks and the variation of their texture and structure are so irregular, and where the probability of several advances and retreats of the ice-sheet is so strong, it is entirely unwarrantable to rule out this hypothesis simply because we cannot give immediate reason for the location of individual drumlins. There is no such hesitation in ascribing sand dunes to the variation in the load and carrying power of the wind, even though the distribution of sand dunes on desert surfaces appears to be fortuitous.

Mr. Upham finds reason to conclude that his explanation of the origin of drumlins confirms a growing belief in the essential unity of the glacial period, although the ice-sheet may have had many oscillations back and forth; and that it therefore contradicts the various arguments that have been brought forward in favor of its division into strongly separated epochs. I fully agree with him that the occurrence of washed gravels and of forest beds between layers of till, by which the complexity and subdivision of the glacial period was first argued, does not inevitably lead to such a conclusion; but on the other hand I believe that evidence of quite another character, based on the work done by rivers between two ice advances, as well as on the greater or less weathering and general wasting of different drift deposits, gives good reason for separating successive advances of the ice-sheet by a measure of time fully as long and probably much longer than

that of the post-glacial period. Yet I believe still further that the only logical position of a glacialist at present is that taken by Chamberlin before the International Geological Congress at Washington in 1891; it is proper enough to state that such and such observations lead to the belief, more or less provisional, that the ice-sheet advanced twice or thrice, for example, over a certain region, and that the interval between the advances was long or short compared to post-glacial time; it is at the same time entirely unwarrantable at the present stage of glacial investigation to divide post-tertiary time into a definite number of geological periods or epochs, as if no more and no fewer occurred, and as if the subject were settled. Such a conclusion is an unsafe provision with which to undertake field work, because it will inevitably lead to special interpretations of observed phenomena. The proper division of post-tertiary time into glacial and interglacial epochs is still an unsolved problem; the very criteria by which the division or unity may ultimately be decided are still in discussion; but the unity of the glacial invasion seems to me one of the least likely solutions, in as much as every year is adding to our knowledge of the extraordinary complexity of its record.

Mr. Upham refers in one part of his theory to the relative duration of the glacial Lake Agassiz and the post-glacial Lake Michigan; following Andrews in concluding that the latter has endured about ten thousand years, while the former endured only one thousand years. This ratio is determined by the amount of shore work done along the margins of the lakes. The conclusion can not be accepted as final, because it is not yet shown that the rate of work in the two lakes was the same: just as the conclusions as to the age of Niagara Falls were all shown to be faulty when it was made probable that the volume of falling water, and hence the recession of the falls also, was variable. It is possible that Lake Agassiz was frozen over during a considerable part of the year, and that its shore work was thus greatly retarded. It is also possible that a considerable part of the area of Lake Agassiz was for much of its life occupied by a lobe of ice, thus diminishing the swing of its waves. Hence a conclusion that rests on the very brief duration of Lake Agassiz as a postulate is not an unavoidable conclusion, while our knowledge of the duration of that remarkable lake is open to varying interpretations. And in reply to Mr. Upham's answer on this point that certain experts think

the closing stages of the last ice invasion had a milder climate than the present, and that Lake Agassiz was therefore seldom frozen over, I may simply say that other experts do not think so. If all experts are agreed, their opinion may be quoted at least to show the fashion of thought at the time, if not to demonstrate a certain conclusion; but when experts differ greatly in their opinions, it is their reasons and not their opinions that should serve as the foundation for further theorizing. This is the more important as a principle of work, because it is so often the case that a carefully guarded opinion or a cautiously qualified suggestion in the original statement becomes a definite opinion in the first quotation, a conclusion in the next quotation, and an established fact in its popular rendering.

It may seem from these remarks, Mr. President, that I am taking only an antagonistic attitude towards Mr. Upham. Such is not my feeling. We are still, as we have been for a number of years, working together towards a common goal, along with others who are striving in the same direction. Our work is not mechanical, according to a set pattern, and it must therefore be flavored by our individual opinions on the many questions that are always involved in so complicated a problem as this. We agree about as closely as field geologists may on many questions; but we seem to differ rather seriously at present regarding the manner of interpretation and the stage reached by the investigation of drumlins.

Mr. G. H. Barton said: I have been engaged during the last three seasons in studying the drumlins of Massachusetts and mapping nearly their entire distribution over the State, and I am naturally much interested in any and all theories that have been or may be advanced respecting their origin. Especially welcome is a new theory as none of the older seems sufficient to account for all the phenomena presented. Indeed it is probable, as suggested by Professor Davis, that the accumulation of these hills may be due to different causes and that no one general theory will account for their origin in all cases.

Various areas give different types as seen most readily in comparing the more rounded and slightly lenticular hills in some parts of Massachusetts with the extremely elongated hills of central New York. In one area they are found scattered over the

country as single individuals, with occasional groups of two or three lying side by side, but each one of the group being a definite, well-formed drumlin. In another area they occur in large irregular masses more or less sculptured into drumloid forms.

Their distribution, as related to elevation above the sea, has a wide range, their bases resting on the one hand below sea-level, on the other at an elevation at least eleven hundred feet above the sea.

The influence of the original topography seems small as they are distributed alike over comparatively level plains and over highly broken areas. In certain areas the present topography is entirely controlled by their undulating outlines, in others so little as to have no noticeable effect, as in instances in which they sit in valleys with their summits entirely below the tops of the rock walls enclosing them. Again they are found perched on steep rock slopes so that the summit of one is below the base of its immediate neighbor.

Another feature as regards their distribution has so far attracted little attention. When in groups of two, three, or more, and also in the large irregular masses, there is a decided tendency to a parallel relation between the lines connecting the centers of the members of the smaller groups, the lines forming the longer axes of the irregular masses, and the front of the ice-sheet now represented by the terminal moraines. This arrangement suggests at a glance the theory held by several prominent geologists that drumlins are formed from a terminal moraine eroded and sculptured into their present forms by the later advance of the ice-sheet. A very strong argument against this view, however, is the difference in texture between the varying composition of terminal moraines and their generally loose structure and the very compact texture and homogeneous composition of the till in drumlins.

The theory now advanced by Mr. Upham may, very probably, account for the origin of a portion of these accumulations, but serious objections arise against its universal application. Professor Davis has already stated most of these. Especially strong is the argument of the extremely local origin of the till in drumlins.

To the objections offered by Professor Davis I will add but one. During the melting of the ice-sheet sufficient to accumulate the former englacial till into a thick superglacial stratum, lines of

drainage would be formed, developing a series of ridges and valleys parallel with the motion of the ice-sheet and transverse to its front. This would cause the thicker accumulations of till in these valleys and we should expect to find drumlins, if formed from such accumulations, having a tandem arrangement in lines parallel to the direction of motion of the ice-sheet instead of lying side by side and presenting a parallel arrangement to this front.

General Meeting, December 7, 1892.

President W. H. Niles in the chair. Fifty persons present.

Mr. L. S. Griswold described some Indian quarries in Arkansas.

In the mountainous region of western central Arkansas there is an extensive formation of pure siliceous rocks, which furnish the well known Hot Springs' novaculites. The hardest portions of this formation were used by the Indians as a material of which to fashion some of their implements long before the advent of white men. The rock is brittle and breaks with a fine conchoidal fracture, giving sharp edges, so that it is particularly adapted to the manufacture of points for arrows or spears, and such seems to have been its chief if not its exclusive use. The points are now found throughout the region, and are made after many different patterns.

Although the rock is very generally exposed, the Indians learned, evidently, that the surface rock was not suitable for their purpose, and so at chosen localities they opened quarries. The work of quarrying was accomplished by means of hammers of tough sandstone or quartzite, aided by the action of fire. By these means pits of considerable size were excavated. At two localities in particular the quarrying has been extensive; one about a mile east of Hot Springs on a spur of Indian Mountain, the other about two miles northeast of Magnet Cove. At the former locality there are three pits having the shape of inverted cones, averaging in size about sixty feet in diameter by twenty in depth. The present form is not the original one but has been given by the falling in of the waste chips which were piled high around the edges of the pits. At the same locality stone was also quarried from bold ledges on the mountain side. Near Magnet

Cove the work was even more extensive; the excavations here commonly have an oval form, with a longer axis, sometimes over a hundred feet in length, and they extend almost continuously along the crest of a high ridge, changing the shape of the crest from a rounded back to a trough for a distance of over a mile.

These old excavations have long been known to Americans, and several theories have been proposed to account for their existence. United States Geologist, G. W. Featherstonhaugh. in 1834 visited the pits near Hot Springs, noted the hammers round about, and pronounced the pits Indian quarries. At some later date the idea grew among the people of this part of Arkansas that these hollows were old Spanish mines; based upon this idea, many mines have been started in the area with the hope of finding gold or silver. A recent geologist after a very hasty examination thought the pits represented the bowls of former hot springs. We may now feel sure, however, of the Indian origin of these pits, since a careful examination by Mr. W. H. Holmes, of the Bureau of Ethnology, shows that all the evidence supports this idea.

Prof. Roland Thaxter gave an account of the Myxobacteriaceae, a new order of Schizomycetes. See The botanical gazette, Dec. 1892, v. 17, p. 389-406, pl. 22-25; Jan. 1893, v. 18, p. 29-30.

General Meeting, December 21, 1892.

President W. H. Niles in the chair. Fifty-five persons present.

The President announced the death of Sir Richard Owen, an Honorary Member of the Society since August 21, 1839, and of Prof. John Strong Newberry, a Corresponding Member since September 3, 1856.

It was announced that the following Corporate Members had been elected by the Council: Messrs. John Adams, E. C. Fitz, N. S. French, W. D. Grier, Miss H. A. Hill, Miss L. F. Peirce, Mrs. M. E. L. Saville, Messrs. T. W. Vaughan and Erving Winslow.

Mr. W. F. Ganong gave a detailed account of some new experiments upon the absorption of liquids by aerial parts of plants; the conclusion reached was that ordinary plants when uninjured probably do not absorb any water through aerial parts, certainly not enough to be of any use to them.

Mr. S. H. Scudder described the formation of the abdominal pouch in Parnassius. (See Trans. ent. soc. London, 1892, p. 249–253.)

Prof. W. H. Niles remarked upon columnar structure in stratified rock.

General Meeting, January 4, 1893.

President W. H. Niles in the chair. Seventy-seven persons present.

Prof. W. G. Farlow gave an account of some of the botanical establishments of Europe.

Dr. J. Eliot Wolff, with the aid of a series of lantern slides, explained the application of the microscope to the study of rocks.

General Meeting, January 18, 1893.

President W. H. Niles in the chair. Sixty-eight persons present.

The President announced the death of Prof. John Obadiah Westwood, an Honorary Member of the Society since November 3, 1841.

Prof. W. M. Davis read a report on the glacial sand-plains of eastern Massachusetts.

General Meeting, February 1, 1893.

President W. H. Niles in the chair. Forty-two persons present.

The following paper was read :—

A NEW INSTANCE OF STREAM CAPTURE.

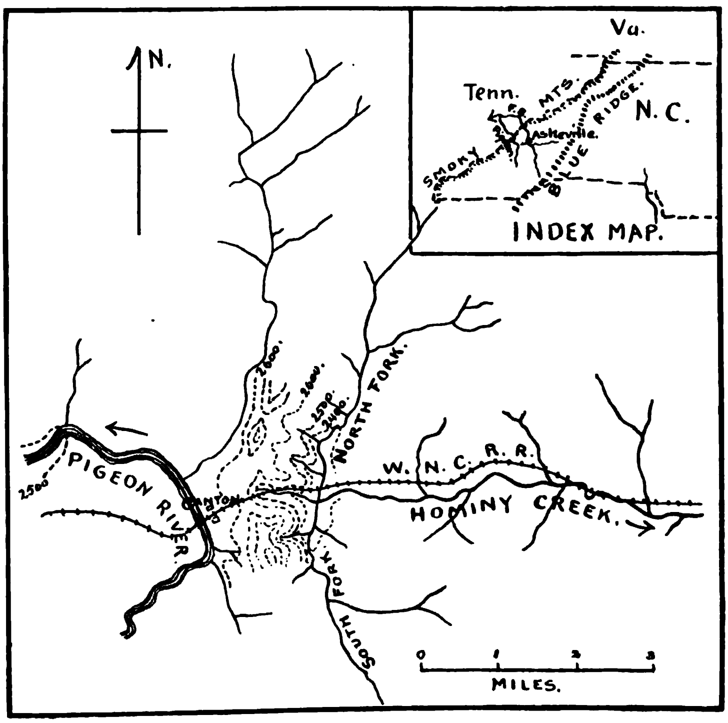
BY HUNTER L. HARRIS.

Two neighbor streams of diverse direction of flow often differ considerably in degree of activity, due mainly to differences in slope and consequent velocity. In such cases the more active stream often works its way backward at the head, pushing the

divide nearer and nearer to the other stream. This occasionally goes so far that the slower stream is tapped and part of its waters drawn off through the main channel of the pirate stream. The resulting system of drainage often shows a back-set position of the tributaries, like the barbs upon an arrow, due to the maintenance of the position which they held when they discharged their waters through the original slower stream.

A typical instance is that of the Upper Engadine of Switzerland, in which the Maira, flowing south-west, has cut back and captured a section of the slower Inn, flowing north-east, together with several of its headwater tributaries. These tributaries retain their general original position except where they enter the pirate stream, and hence their peculiar back-set character in the resulting system.

An instance of such stream capture is found fifteen miles west from Asheville in the Appalachian section of North Carolina. Hominy Creek, a rapid flowing tributary of the French Broad,



has cut its way back until it now heads within half a mile of the relatively inactive Pigeon River. This stream at its head is considerably below the level of Pigeon River and its fall is much more rapid throughout its course. The peculiar barbed attitude of North and South Fork of Hominy suggests that they were formerly tributary to Pigeon River near the point where they now enter Hominy Creek, and other features seem to bear out this view. In course of time Hominy Creek will, unless artificially restrained, gnaw back into the bed of Pigeon River itself and cause a radical change in the drainage system of a large area.

Dr. H. P. Bowditch spoke of Sir Francis Galton's work on finger prints and on composite photography.

General Meeting, February 15, 1893.

President W. H. Niles in the chair. Thirty-one persons present.

It was announced that the following Corporate Members had been elected by the Council: Miss A. F. Armes, Mrs. E. R. Cormier, Harrison G. Dyar, Miss M. L. Ells, Abner Hatfield, Miss E. J. Hill, and Mrs. C. A. Kennard.

The following paper was read: —

FURTHER EVIDENCE OF CANNIBALISM AMONG THE INDIANS OF NEW ENGLAND.

BY HENRY W. HAYNES.

Some ten years ago I laid before this Society certain evidence tending to establish the fact of the practice of cannibalism among the Algonquin tribes of New England.[1] This had been obtained from various shell-heaps to be found on the shores of Frenchman's Bay, in the Island of Mt. Desert, in Maine. Since then other evidence to the same effect has fallen under my observation, in the same region. In the town of Lamoine a fine headland juts into Frenchman's Bay, about opposite to Salisbury Cove, on Mt. Desert Island. Along its western shore are plainly to be seen traces of a series of hut-circles, each surrounded by

[1] Proc. Bost. soc. nat. hist., v. 22, p. 60–63.

its heap of debris. In one of these I found an ancient hearth, made of beach pebbles arranged in order at the foot of a large boulder. Close by was a mass of refuse made up of shells and bones, among which were fragments of at least half a dozen human skulls, broken into pieces of considerable size. The teeth showed that they all belonged to youthful persons; and no other parts of the human skeleton were found in the vicinity, although there was an abundance of the bones of such animals as are commonly found in the shell-heaps of Maine. Evidently the theory of an interment will not account for the presence of these skulls, while that of cannibalism seems to explain it clearly.

I wish to exhibit tonight a remarkable relic also found in a shell-heap in West Gouldsboro', on the east side of Frenchman's Bay. It is an implement made out of the upper half of a human humerus. The ball of the joint forms the handle, while the shank has been cut down one half and sharpened to a point. There is in the Peabody Museum an implement of a similar character, found many years ago by Mr. J. Elliot Cabot, in a shell-heap in Ipswich, Mass. It is described by Dr. Jeffries Wyman as "an upper arm bone, which had been worked by man, but the worked end having been partially destroyed, leaves it doubtful as to the nature of the implement intended. This bone, in its curves and muscular markings corresponds with the human humerus, but it is unusually slender, and it is compressed at the upper part. A careful comparison, however, justifies the conclusion that it was a part of a human skeleton."[1]

In the present instance there is no question about the shape and character of the implement, and that it has been fashioned out of a human bone. In a popular work upon prehistoric times I find a figure, representing a similar tool, that has been fashioned out of half of a human radius; this belonged to Dr. Prunières, and doubtless came from some of his many explorations in southern France.[2]

Similar objects made out of the bones of animals are quite common in the lake-dwellings of Switzerland and elsewhere.[3]

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[1] Second annual report Peabody museum Amer. archaeology and ethnology, 1869, p. 16.

[2] Nadaillac's Prehistoric peoples. (Translation) p. 111, f. 29.

[3] Mortillet's Musée préhistorique, pl. 38, f. 311, 312.

In the French language these are designated as *poinçons*, which the translator of Nadaillac's work has rendered by *stilletto*, though I should suppose that *bodkin* would designate its purpose more clearly, since they are commonly supposed to have been used for making fishing-nets. Prof. Otis T. Mason, however, in an article on the basket-work of the North American Indians, figures a precisely similar object, from Coahuila, Mexico, which he calls a *bone-pricker*.[1] He states that "the tool almost universally used in the manufacture of baskets is a bone awl, or pricker, and the makers are the women" (page 291). Subsequently he quotes (page 303) an explanation by Dr. Palmer, of a peculiar method in which these were used, "In Utah, Arizona, southern California, and New Mexico the Indians depend solely upon this plant [*Rhus aromatica*, var. *triloba* (squawberry)] for material out of which to make their baskets. It is far more durable and tougher than the willow, which is not used by these Indians. The mode of preparation is as follows: The twigs are soaked in water to soften them, and to loosen the bark, which is scraped off by the females. The twigs are then split by the use of the mouth and both hands. Their baskets are built up by a succession of small rolls of grass stems over which these twigs are firmly and closely bound. A bone awl is used to make the holes under the rim of the grass for the split twigs. Baskets thus made are very durable, will hold water, and are often used to cook in, hot stones being dropped in until the food is done."[2] I think there can scarcely be a doubt that the present implement was used for the purpose of basket-making. The early comers to New England speak in the highest praise of the excellence of the basket work of the natives. In the narrative of the first exploring party of the Pilgrims, November 16, 1620, it is said that "we found a little old basket, full of fair Indian corn; and digged further, and found a fine great new basket, full of very fair corn of this year. . . . The basket was round and narrow at the top. It held about three or four bushels, which was as much as two of us could lift up from the ground, and was very handsomely and cunningly made."[3]

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[1] Smithsonian report, 1884, pt. 2, pl. 64.

[2] Amer. nat., 1878, v. 12, p. 597-598.

[3] Mourt's Relation (Young's edition), p. 133, 144; cf. Bradford's History (Deane's edition), p. 82.

So, also, Wood tells us that "in summer they gather flags of which they make mats for houses, and hemp and rushes, of which they make curious baskets, with intermixed colors and portraitures of antique imagery. These baskets be of all sizes from a quart to a quarter."[1]

The fact that in any region human bones have been found fashioned into domestic utensils would not, by itself, be sufficient proof that cannibalism prevailed among the tribes where such objects have been discovered; but it lends strong corroboration to the other evidence that such a custom existed among the natives of this country. This evidence is to be found both in the narratives of eye witnesses, and in those archaeological discoveries to which I have alluded in the article previously referred to. Such archaeological evidence from New England, however, is comparatively rare, so that every additional example becomes of interest. As even the ample proof of the practice of cannibalism discovered by Prof. Jeffries Wyman in the Florida shell-heaps has been regarded in some quarters as insufficient, this confirmatory evidence acquires added significance.[2]

Dr. S. J. Mixter described an old beaver dam discovered at Hardwick, Mass.

General Meeting, March 1, 1893.

President W. H. Niles in the chair. Seventy-five persons present.

The President announced the death of Dr. Henry Wheatland, a Corresponding Member since December 20, 1848, and of the Rev. R. C. Waterston, a Member since January 4, 1860.

Prof. E. S. Morse described a curious Aino toy. (See Bulletin Essex institute, v. 25, p. 1–7.)

Dr. C. Willard Hayes gave an account of the joint work of himself and of Mr. M. R. Campbell on the structural features of the southern Appalachians.

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1 Wood's New England's prospect (Prince society edition), pt. 2, ch. 20, p. 107; see also Roger William's Key into the language of America, ch. 6.

2 Fresh water shell-mounds of the St. John's River, Florida, p. 67–78. This conclusion has been questioned by S. T. Walker, Smithsonian report, 1879, p. 419; and by Cartailhac in Matériaux, v. 22, p. 291.

General Meeting, March 15, 1893.

Vice-President B. Joy Jeffries in the chair. Forty-one persons present.

Prof. H. C. Ernst described a new pathogenic Bacillus.

The following papers were read :—

DEFLECTED GLACIAL STRIAE IN SOMERVILLE.

BY WARREN UPHAM.

Boulders and smaller rock fragments held firmly frozen in the bottom of the ice-sheet, and especially the fine gravel and sand caught beneath these masses, were ground and rasped as the glacial currents carried them onward. Multitudes of blocks and great amounts of gravel and sand, thus acting as graving tools in the grasp of the ice, were worn to the finest powder, and considerable depths of the bed-rocks were eroded, much being pulverized, while the jointed structure often permitted blocks of large and small size to be loosened and swept away in the basal portion of the ice. Because of their mutual attrition, like upper and nether millstones, many of the drift boulders and pebbles, and nearly the entire surface of the underlying rocks, are distinctly planed and scratched. These marks, or striae, on the bed-rocks are very interesting, because they record the directions of the ice motion.[1] They are found on all the rock surface of Massachusetts, when overlying drift is removed, as on the borders of quarries and where the rock is exposed in grading streets or digging cellars; but on many portions of the natural rock outcrops they have been effaced by the action of the weather.

During my recent examination of the area of Somerville, the city of my residence, lying next northwest and north of Boston and Cambridge, for the purpose of preparing a sketch of its geology to be published in connection with a history of its first fifty years which were completed in 1892, numerous localities having widely diverse courses of the glacial striae were dis-

[1] Descriptions of the various types of glacial striation, planation, and embossment, with discussion of their methods of origin and of their significance as evidence of the prevailing ice currents and of deflections during the glacial recession, are given in Prof. T. C. Chamberlin's memoir, "The Rock-Scorings of the Great Ice Invasions." Seventh annual report, U. S. geol. survey, for 1885-86, p. 147-248. illustrated by fifty figures in the text, mostly engraved from photographs.

covered, testifying of great deflections of the ice currents. Elsewhere throughout glaciated regions, the striae of any district are generally parallel, or deviate only slightly from one direction; but here, probably more than in any other area of equal extent that has ever been thoroughly examined, the courses of glaciation have a very wide range, from south-southwest to south, southeast, east, and even east-northeast.

Usually the striae on any small space of the rock exposures in Somerville are all parallel, or include only a few exceptional scratches crossing the others with small angles of divergence; but occasionally intersecting striae have in nearly equal proportions two, three, or many widely varying courses. Nearly always each of the individual scratches on the rock is straight, extending commonly a few inches, but sometimes plainly continuous as a single line several feet long. It is evident, therefore, that the currents of the ice-sheet were deflected here from one course to another and even to several successive courses in so short a time that it allowed no great amount of erosion of the rock beneath.

Several instances of exceptional curving striae which I have found on the ledges of Somerville, turning in every case toward the east from their southward course, seem to record such deviation while it was taking place. Most frequently, however, the records of different directions of the ice currents are preserved on contiguous spaces of the rock, all the striae in one case bearing, for example, S. 20° E., while at a distance of a few feet another spot may be just as uniformly striated S. 60° E. In such places a thin covering of drift on the rock surface with most southerly course protected it from erosion by the later glacial current passing more eastward. It is thus known that there was a definite plane between the moving base of the ice with its enclosed drift and the undisturbed subglacial drift deposits or ground moraine. Any accumulation of the ground moraine, however, after having received additions for a considerable time from the overriding ice-sheet, was liable, on account of changes in the action of the glacial currents, to be partially or wholly planed off and carried forward, like the detritus supplied from the bed-rocks, wherever they were exposed.

The courses in which the ice-sheet moved over Somerville have been observed in many places, as noted in the following list, which is arranged in the geographic order of the rock outcrops from east to west and south to north.

Courses of Glacial Striae.[1]

Eastern and Central Portions of Somerville.

Crescent Street, mostly S. 30° E., crossed by others from S. 15° to 40° E.

Franklin Place, S. 30° E.

Between the last and Myrtle Street, nearly horizontal striae on a steep rock face, S. 75° E. to N. 85° E.

Granite Street quarry, on its northwest border, S. 30° E.

Avon Street, about 25 rods west of School Street, S. 25° E.

Near the corner of Pearl and Wigglesworth Streets, S. 20° E.

Several rods northwest from the last and about ten rods southeast from the corner of Walnut and Veazie Streets, S. 20° E., intersected by various courses to S. 55° E.; but in other spots, 5 to 15 feet southeast from this, only S. 35° E.

Corner of Pembroke and Sycamore Streets, intersecting striae, S. 25° to 50° E.

Near the corner of Tennyson and Medford Streets, in one place, S. 30° E.; but on another small exposure, twenty feet farther north, S. 45° E.

In Tennyson Street, halfway from Medford to Forster Street, S. 25° E.

Area North of Winter Hill.

Old quarry about 200 feet northeast from the corner of Temple and Derby Streets, on south border, S. 35° E., with a few intersecting, S. 15° E.

Northern border of this quarry, intersecting, S. 25° E., S. 40° E., and S. 75° E. These are also crossed in some places by very fine and delicate striae, clearly of glacial origin, bearing S. 30° W., which seem to be probably the latest of all, being due to a deflection when the ice-front, retreating past this place, was indented by some small hollow, toward which the glacial current would be turned from a distance of only a few rods.

[1] Referred to the true or astronomic meridian, from which the magnetic meridian has a variation of 11° 30′ west of north, according to the isogonic chart for 1890 published by the U. S. coast and geodetic survey.

A short distance west of the foregoing, on the east border of the most southern quarry now worked between Winter Hill and the Mystic River, mostly S. 30° E., crossed by other striae also very distinct, bearing S. 40°–50° E.

Thirty feet south of the last, S. 40° E. and S. 60° E., intersecting.

Northeastern and lower part of McCarty's large quarry, just north of the last, at his blacksmith shop, S. 45° E.; fifty feet farther north, S. 35° E.; and about a hundred feet onward to the north, S. 10°, 15°, 30°, and 40° E., all very distinct, intersecting on the same surface. These places are at the northeastern base of the quarried hill.

Northwestern high border of McCarty's quarry, S. 45° E.

Top of this rock hill, near the southwest corner of the same quarry, S. 50° E.; with variations from S. 40° to S. 60° E.

Again, on the top of this hill about a dozen rods west of the last, at the northern border of the southwestern quarry, S. 65° E., crossed by others ranging to N. 75° E., the latter being very distinct but only short and shallow striae.

Northeast border of old quarry in the west part of this hill, S. 55° to 65° E.; also, S. 35° E.

Northwest border of this quarry, nearly as high as the top of the hill, due S., and all directions thence to S. 55° E., intersecting. The prevailing course is S. 40° E.

West end of Jacques Street, southwest of the quarried hill, S. 40° to 55° E.

Corner of Mt. Vernon Avenue and Meacham Streets, S. 50° to 55° E.

Brooks Street, near the west end of Heath Street, S. 30° E.

Near the corner of Brooks and Meacham Streets, S. 40° E. and S. 80° E., intersecting.

South side of Main Street, on the Medford line, excellent striae, extending five to ten feet, S. 35° E.

East of Fremont Street and about twenty rods northeast of Main Street, S. 50° E.

West of Fremont Street, ten rods northwest from the last, S. 45°–55° E.

Ten feet farther north, many striae, S. 50° E., crossed by many others, S. 80° to 85° E. and due E., but none bearing between these two sets. The eastward striae doubtless record the latest ice movement.

About four rods north of Meacham Street, opposite Brooks Street, S. 45° to 50° E.; and again ten rods to the east from this place, S. 45° E.

South edge of quarry close west of Dunning Brothers' coal wharf, S. 60° E.; three rods northwest of this quarry, S. 50° E.; and about ten feet farther north, S. 30° E.

Beside Mystic Avenue and river close east of the Medford line, S. 40° E.

On ledges at south edge of marsh, about thirty rods west of the last, S. 50° to 60° E.

Northeast line of Joseph Street, Medford, between Leyden and Sanger Streets, S. 45° E.

Corner of Joseph and Sanger Streets, S. 75° to 80° E.

Northwest line of Sanger Street, about ten rods southwest from the last, S. 35° to 40° E.

Corner of Main and Dexter Streets, S. 25° E.

Vicinity of Lowell, Beech, and Cedar Streets.

Near the corner of Lowell Street and Somerville Avenue, about six rods east of the Fire Department engine house, S. 5° W. to S. 30° E.; about eight rods north of this, S. 60° to 75° E.; about four rods northwest of the last, S. 5° E. to S. 40° E. and S. 70° E., intersecting; and ten feet farther northwest, only S. 5° E., which was probably the earliest of these courses.

Lowell Street, about forty rods north of the engine house, S. 20° E.

Near the angle of Beech Street, mainly S. 15° E.; also, intersecting, S. to S. 20° E.

Lexington branch of the Boston and Lowell Railroad, about fifteen rods east of Cedar Street, S. 70° E.

Near Willow Avenue.

Between Willow Avenue and Arnold Street, on the southwestern part of the large outcrop of diabase, S. 25° to 30° E., crossed by other striae, S. 50° E. The scratches and furrows of both sets are abundant and nearly straight, many of each being from a sixteenth to a quarter of an inch deep.

The portion of this ledge twenty to thirty feet north of the foregoing is striated uniformly S. 30° E.

Ten to twenty feet farther northeast, mainly S. 25° E., but with many intersecting striae bearing due S

Again, thirty to forty feet east of the last, excellent striae bear S. 70° E.

Next, from ten to twenty feet still farther east, the striae, also excellent as to their extent and depth, bear mainly in two sets, S. 80° to 85° E. and N. 85° E. Here and there, however, straight striae cross these in various courses to N. 60° E. Others curve from an eastward to a north-northeastward course in their length of three to four inches.

Fifteen to twenty feet still onward to the east, striae on closely adjoining spots bear respectively S. 60° E. and S. 80° E.

Finally, from twenty-five to forty feet yet farther east, upon an admirably glaciated surface from ten to fifteen feet across, the striae all bear S. 30° E.; except that in one place, for two or three feet, these are intersected by a few short, deep furrows, bearing S. 80° E. Nearly the whole of this surface was thinly covered by drift while the deflected S. 80° E. glacial current swept over it.

All these observations of striae near Willow Avenue are on the upper part of the northern or stoss side of this slightly projecting diabase ledge, where no topographic features of this knoll or the surrounding land could tend to turn the glacial currents from their normal courses due to the varying pressure of the ice-sheet.

West Somerville.

Four to five rods west of the Powder House, on a portion of the rock uncovered in grading for the new park, mostly S. 25° E., crossed by a few others, S. 15° E.

About ten rods south of the Powder House, S. 25° E.

Liberty Avenue, near Francesca Avenue, S. 40° E.

Kidder Avenue, close west of Liberty Avenue, also S. 40° E.

Kidder Avenue, south sidewalk, near Elm street, S. 25° to 30° E.

Summit Street, two places, S. 30° E. and S. 25° E.

Billingham Street, northwest sidewalk, nearly opposite Summit Street, S. 30° E.; and about four rods west of the last, S. 25° E. These and the last three places previously noted are on very small rock exposures, even with the graded surface.

Clarendon Hill.

At the top of the rock hill quarried by the Somerville street department and hence known as the "City Quarry," S. 30° E.

In a hollow of this rock outcrop, between the last and another summit ten rods farther north, about twenty feet below these summits, S. 10° E. and S. 25° E., intersecting; about twenty feet southeast from the last, S. 35° E. and S. 65° E., likewise intersecting; and again, about forty feet farther southeast, the prevailing and almost sole course on a well-striated surface five feet square is S. 20° E., but two definite glacial striae on the same surface bear S: 5° E.

Twenty-five feet still farther southeast in the same hollow, striae bear S. 25° E.; about thirty feet north of the last, N. 60° to 65° E.; and four feet east of the last, where striae are next seen, N. 70° E.

On the northeastern slope of this rock hill, opposite Packard Street, S. 35° E.

Moore Street, S. 20° to 25° E.

Clarendon Avenue, east border of E. S. Sparrow's quarry, commonly S. 20° to 30° E.; but in one place, S. 10° to 15° E., crossed by other striae, S. 20° W. The striae bearing S. 20° W. are numerous and all straight, one to three inches long, covering some small surfaces, and elsewhere intersecting the more eastward courses.

West border of Cambridge Stone Company's quarry, near Endicott Avenue, due S.; about four rods farther southwest, S. 25° W.; and seven feet east of the last, S. 10° E. and S. 25° W., intersecting.

South side of College Hill.

Near the Artificial pond, in several places, respectively, S. 35°, 40°, and 45° E.

Close south of Professors' Row, several places, S. 30° to 35° E.

Between Packard and Curtis Streets, S. 25° to 30° E.

Raymond Avenue, S. 15° to 30° E., intersecting; but in other places here, nearly all S. 25° E.

Corner of Conwell Avenue and Curtis Street, S. 35° E.

An inspection of these notes shows that the prevailing courses of the glacial striae in Somerville bear S. 20° to 30° E.; and

these doubtless represent the direction of the ice movement here during a considerable time in the later part of the Glacial period. In some places, as at the quarries on the south side of Clarendon Hill, perhaps an earlier direction of the ice-flow is recorded by the south-southwestward striae. The most remarkable deflections of the currents, however, causing them to pass east-southeastward or occasionally due east or north of east, over the rock hill quarried north of Winter Hill, on Lowell Street, on the Lexington branch railroad near Cedar Street, on Willow Avenue, and at the City Quarry, appear to belong to the time of departure of the ice-sheet from this region, when its motion was turned toward an open bay melted into the receding ice-border on its seaward side.

Upon Somerville and all the vicinity of Boston the ice-sheet when it extended farthest was probably from 2,000 to 2,500 feet thick, increasing in its depth northward and northwestward. Its currents here moved at that time to the south and south-southeast, but during later stages they were deflected to the east-southeast or even in some places to a due east course. This deflection appears to have been due to the faster melting and retreat of the ice from the ocean on the southeast than from the land surface of southern New England, whereby a large embayment was melted out from the border of the ice upon the present area of Massachusetts Bay, at last turning the currents of the ice here toward that open area on the east.

To the same time as the eastward deflection of the glacial striae we must refer the accumulation of the many drumlins in Somerville, Boston, Cambridge, Everett, Chelsea, Revere, and Winthrop, where the longer axes of these massive oval hills of till trend prevailingly to the southeast and east-southeast, while the striation on the bed-rocks is mostly south-southeast, differing from the trends of the drumlins by 25 to 45 degrees. For example, the altitudes (above mean tide sea level) and trends of the ten drumlins in Somerville are as follows: Asylum Hill, 58 feet, S. 45° E.; Convent Hill, original top before grading, 94 feet, S. 65° E.; Winthrop Hill, on "Ten Hills farm," close southwest of the Middlesex Avenue bridge, 65 feet, S. 60° E.; Prospect Hill, original top before grading, 133 feet, S. 45° E.; Central Hill, 109 feet, S. 60° E.; Winter Hill, 141 feet, S. 70° E.; hill on Beacon Street close southeast of Washington Street, 34

feet, S. 45° E.; Spring Hill, 138 feet, S. 60° E.; Clarendon Hill, whose top on Fairmount Avenue is a drumlin mass of till, 90 feet, S. 50° E.; and Walnut or College Hill, lying mostly in Medford, 155 feet, S. 50° E.

Elsewhere in all the districts characterized by abundant drumlins in this country and the British Isles, their longer axes and the striae are parallel; and it seems sure that both were determined by the currents of the ice-sheet. Their difference in direction in the neighborhood of Boston was doubtless due to a deflection of the motion of the ice here during its final melting, of which we now have ample evidence from these deflected glacial striae in Somerville, and from others, apparently more rare and local, recorded on Cape Ann by Prof. N. S. Shaler[1] and in Nantasket and Cohasset by Prof. W. O. Crosby.[2] Probably further examples of eastwardly deflected striae will be detected by thorough search in all the cities and towns bordering Boston harbor and reaching northeastward to Cape Ann.

Through the time of its maximum thickness and extent the ice-sheet moved south-southeastward across this area, and reached to the terminal moraine of Long Island, Block Island, Martha's Vineyard, and Nantucket; and onward the course of its border was probably east-northeast along the submarine plateaus of the Fishing Banks. But when a mild climate began to cause the glacial boundary to recede northward, the melting probably advanced faster on the area of the Gulf of Maine than in southern New England, so that the ice-front became indented by a deep embayment east of Massachusetts, toward which the latest currents along the coast were deflected. The formation of the drumlins about Boston seems to have taken place wholly during the time of deflected glacial movements, the ground moraine being massed in these hills on account of inequalities in the force and direction of the overriding ice-sheet, when its receding border may have been only a few miles distant. In my previous papers on the drumlins of our district read before this Society in 1879, 1888, 1889, and last November, this relationship of the drumlins to the recession of the ice-sheet has been indicated as probable, of which the discovery of these abundant deflected striae supplies strong confirmation.

[1] U. S. geol. survey, Ninth annual report, for 1887–'88, p. 557, 558, pl. 75.
[2] Boston soc. nat. hist., Occasional papers, 1893, v. 4, p. 141.

Farther inland throughout Massachusetts, Mr. George H. Barton finds the trends of the drumlins prevailingly parallel with the striation, but with occasional exceptions where the longer axes of drumlins vary much from this course, probably because of small indentations in the glacial boundary and consequent divergence of the latest ice-motion from its previous direction.

THE FISHING BANKS BETWEEN CAPE COD AND NEWFOUNDLAND.

BY WARREN UPHAM.

ALONG a distance of about a thousand miles east-northeastward from Cape Cod the submarine border of the North American continent presents very remarkable irregularities of contour. The sea bed there in its descent from the present coast lines to the abyssal depths of the North Atlantic ocean differs entirely from the smooth and gently inclined plane of the submerged continental slope along its next thousand miles south to the Strait of Florida and the Bahama Islands. Instead we find by soundings from Cape Cod to the Grand Bank of Newfoundland that this section of our coast has a profusion of submerged hills and broad plateaus, elevated from 100 to 1000 feet above the intervening valleys and adjacent low portions of the sea bed, from which they rise nearly to the sea level but only in a single instance reach above it, forming Sable Island. These plateaus, covered by water ranging mostly from 10 to 50 fathoms in depth, sustain luxuriant submarine vegetation, abundant molluscan life, and vast schools of cod, haddock, mackerel, halibut, and other food fishes, which almost from the time of first discovery and exploration of this coast have caused its submerged plateaus to be the site of important fisheries and thence to be known as Fishing Banks.

In their order from southwest to northeast, the more extensive of these plateaus are the St. George's, Western or Sable Island, Banquereau, St. Pierre, and Green Banks, and, most northeastern and by far the largest, the Grand Bank of Newfoundland.

St. George's Bank, more frequently called simply George's Bank by the Gloucester fishermen whose fleet of hundreds of schooners is mostly employed in fishing there, extends a hundred and seventy-five miles east from Nantucket and Cape Cod, being connected with the Nantucket shoals by an isthmus which has about 40 fathoms of water. The area of St. George's Bank above the 50 fathom contour line exceeds that of the State of Massachusetts, and has a width of about a hundred miles from northwest to southeast. George's Shoal, on the northwestern part of this plateau, has two spots with only 12 feet of water; while twenty miles west from that highest portion of St. George's Bank, it rises again in the Cultivator Shoal to 18 feet, or only 3 fathoms, below the sea level. About these shoals the ground swells of great storms break with nearly as much grandeur and danger to shipping as on a coast line. The surface of the bank, as shown by the soundings of the U. S. Coast Survey, "is covered with pebbles and small stones, excepting shallow portions and pot-holes, where the material ground down by the sea has accumulated."[1]

North of St. George's Bank, the Gulf of Maine occupies an area of about 36,000 square miles, of which nearly a third part exceeds 100 fathoms in depth, the average for the whole being estimated not less than 75 fathoms. The maximum depth of the western part of the Gulf of Maine is 180 fathoms, found forty-six miles east of Cape Ann; and of its eastern part, at a distance of a hundred miles east-southeast from the last, 199 fathoms, this being close north of George's Bank, in latitude 42° 20′ and longitude 67° 20′. At the mouth of this gulf, between the northeastern border of George's Bank and Brown's Bank, of comparatively small area, which lies halfway thence to Cape Sable, N. S., the soundings are from 150 to 170 fathoms.

Brown's Bank is covered by water from 26 to 50 fathoms deep, and on its north side water of 60 to 80 fathoms divides it from Nova Scotia. Three other small plateaus lie within the next hundred and fifty miles eastward.

[1] "Physical hydrography of the Gulf of Maine." Report of the U. S. coast and geodetic survey, for the year ending June, 1879, p. 175–190. "A plea for a light on St. George's Bank,' Appendix No. 11, *ibid.*, for year ending June, 1885, p. 483–485. The contour of the Fishing Banks, as here described, is shown by Eldridge's Chart from Cape Cod to Belle Isle, 1887 (published by S. Thaxter & Son, 125 State St., Boston).

Continuing in this direction, the large Western Bank and Banquereau stretch two hundred and fifty miles east-northeast, varying from 50 to 75 miles in width, and separated by a breadth of twenty-five to a hundred miles of deep water from the eastern part of Nova Scotia and from Cape Breton Island. On the east half of the Western Bank its highest portion is the wave-built broad sand beach of Sable Island, about twenty-five miles long from west to east, heaped in dunes by the winds. Between Banquereau and Cape Breton Island are some half a dozen small banks, of which the Misaine, about sixty miles long, is the largest and extends farthest northeast.

Next eastward the now deeply submerged preglacial valley of the River St. Lawrence lies at a depth of 260 to 300 fathoms, showing, as Prof. J. W. Spencer has well pointed out, that before the Ice age this part of North America was elevated at least from 1,500 to 2,000 feet above its present height.[1]

Beyond this great submarine valley the St. Pierre Bank, covered by only from 22 to 50 fathoms of water, reaches about a hundred and twenty-five miles from northwest to southeast, with a width of thirty to sixty miles. On the north this bank is divided from the Miquelon Islands by water from 61 to 63 fathoms deep.

Soundings of from 80 to 96 fathoms separate the St. Pierre from Green Bank, of which the latter has a length of about sixty miles from north to south with half as great width, being in its turn separated from the Grand Bank by water of 64 fathoms. Farther east the deep water between Cape Race, Newfoundland, and the Grand Bank is mostly from 80 to 100 fathoms, and in one place 115 fathoms. On the northwest, however, Placentia Bay of Newfoundland has maximum soundings of from 125 to 147 fathoms, being thus probably 67 fathoms deeper than any outlet from it to the depths of the North Atlantic.

The Grand Bank has approximately the outline of an equilateral triangle measuring from 275 to 300 miles on each side, or very nearly the same as the far more irregular area of Newfoundland. Its depth of water ranges mainly from 25 to 50 fathoms, and its shallowest places are found along the northern

[1] "The high continental elevation preceding the Pleistocene period." Bulletin G. S. A., vol. 1, 1890, p. 65–70, with map of the preglacial Laurentian river. Also in the Geol. mag., ser. 3, v. 7, 1890, p. 208–212.

edge, on which are the Virgin Rocks, with only from 4 to 10 fathoms; the rocky eastern shoals, stated to be thirty in number, with from 5 to 25 fathoms, but having channels of from 40 to 50 fathoms between them; and, farther east, Ryder's Bank, with only 3½ fathoms, though surrounded by from 38 to 40 fathoms of water. The western part of the Grand Bank contains an apparently enclosed basin, about fifty miles long, called Whale Deep, which has maximum soundings of from 60 to 67 fathoms, with a muddy bottom. Northward from this basin a distance of twelve miles, with soundings from 48 to 53 fathoms, divides it from the deep water outside the bank; and on the south thirty miles, with mostly about 50 fathoms of water, lie between the Whale Deep and the steep descent into the abyssal ocean.

If this portion of the continental border from Cape Cod to the Grand Bank southeast of Newfoundland could be again uplifted as when the St. Lawrence in preglacial times flowed out to sea between the highlands which now form the Misaine, Banquereau, and St. Pierre Banks, we should behold nearly as much diversity of valleys, ridges, hills, plateaus, and all the forms of subaerial land erosion, as is exhibited by any portions of the adjacent New England states and eastern provinces of Canada. During a long time of high elevation closing the Tertiary era and initiating the Quaternary, this region was eroded by rains, rills, brooks, and rivers, cutting such profound chasms as the sublime Saguenay fjord, reaching 800 feet below the sea level and enclosed by precipitous rock walls, 1,500 feet high, until the cold climate induced by the increasing altitude covered the land with an ice-sheet which gradually became thousands of feet thick and at last by its weight appears to have brought about the Champlain depression, the return of a temperate climate, and the final melting of the ice. The submerged channels of outlet from the Gulf of Maine and the Gulf of St. Lawrence, and the less profound valleys that divide the Fishing Banks from each other and from Nova Scotia and Newfoundland, with the distinct stream courses revealed by soundings on all the larger banks, as St. George's, Western, Banquereau, St. Pierre, and the Grand Bank, prove that this region during a comparatively late period of geologic time was a land area, its maximum elevation being at least 2,000 feet higher than now.

That the period of uplift was the late Tertiary and early Quaternary is shown by the age of the strata which, beneath a thin envelope of glacial drift, form these submarine banks. In 1877 Prof. C. H. Hitchcock suggested that the Fishing Banks are of Tertiary age[1]; and much earlier Agassiz had taught his classes that they must consist superficially of drift, the eastern continuation of the drift sheet of the northern United States and of Canada. Both these theories were fully justified in 1878, when in the service of the U. S. Fish Commission at Gloucester, Mass., I gathered from the fishermen of that port many specimens of rocks that had been brought up from the bottom of the Fishing Banks by their lines becoming entangled in the coralline growths attached to these rock masses. A large proportion of the stones so drawn up are rounded and subangular fragments of granitic, gneissic, and schistose rocks, evidently transported to their present position through the agency of ice, either by an ice-sheet during the Glacial period, as was doubtless true for a large part of this drift, or by icebergs and floes, which still are contributing yearly to the drift of the Grand Bank. Apparently a smaller proportion, but more likely to be brought ashore by the fishermen, consists of fossiliferous sandstone and limestone, often well filled with shells or with their empty casts. Many of these fossiliferous rock fragments, varying from one pound to a hundred pounds or more in weight, were collected and submitted to Prof. A. E. Verrill for determination of their species, concerning which he wrote as follows in the American journal of science for October, 1878 (ser. 3, v. 16, p. 323–324).

Among the most important results of the investigations made by the party connected with the U. S. Fish Commission, stationed at Gloucester, Mass., during the present season, is the discovery of fragments of a hitherto unknown geological formation, apparently of great extent, belonging probably to the Miocene or later Tertiary. The evidence consists of numerous large fragments of eroded, but hard, compact, calcareous sandstone and arenaceous limestone, usually perforated by the burrows of *Saxicava rugosa*, and containing in more or less abundance fossil shells, fragments of lignite, and in one case a spatangoid sea-urchin. Probably nearly one-half of the species are northern forms, still living on the New England coast, while many others are unknown upon our coasts and are apparently, for the most part, extinct. From George's

[1] Geology of New Hampshire, vol. 2, p. 21.

Bank about a dozen fossiliferous fragments have been obtained, containing more than twenty-five distinct species of shells. Among these one of the most abundant is a large thick bivalve (*Isocardia*) much resembling *Cyprina Islandica* in form, but differing in the structure of the hinge. This is not known living. *Mya truncata*, *Ensatella Americana*, and the genuine *Cyprina* are also common, together with a large *Natica*, a *Cyclocardia* (or *Venericardia*) allied to *C. Borealis* (Con.), but with smaller ribs, *Cardium Islandicum*, and also various other less common forms. These fragments came from various parts of the bank, including the central part, in depths varying from 35 to 70 fathoms, or more.

From Banquereau, N. S., we received one specimen of similar rock, containing abundant fragments of a large bivalve, and about a dozen other species, among which are *Fusus* (*Chrysodomus*) *decemcostatus*, *Latirus albus* Jeff. (?), unknown species of *Turritella*, etc. From the Grand Bank two similar specimens were received. One of these, from thirty-five fathoms, lat. 44° 30′, long. 50° 15′, contained numerous specimens of *Cyprina Islandica* in good preservation.

. . . .

At present it appears probable that these fragments have been detached from a very extensive submerged Tertiary formation, at least several hundreds of miles in length, extending along the outer banks, from off Newfoundland nearly to Cape Cod, and perhaps constituting, in large part, the solid foundations of these remarkable submarine elevations.

The collections here described, belonging to the U. S. Fish Commission, are under Professor Verrill's care in the Yale University museum; but no further investigation of them has been made. It has been my hope to secure another similarly large collection and to give it attentive study, but other duties have prevented this. Though the fishermen doubtless now draw up on their lines as many of these specimens of the bed-rocks of the banks as they did fifteen years ago, most of them are immediately thrown away and fewer are brought ashore than at that time when the work of the Fish Commission in Gloucester stimulated a worthy rivalry among the captains and fishermen to bring in everything zoological or geological which might possibly be of scientific interest for the Fish Commission. Visiting Gloucester during a few days in the summer of 1890, my only opportunity for this collecting within recent years, I was able to obtain only a few specimens of these fossiliferous rocks, chiefly through donation by Dr. Thomas Conant and Mr. Everett P. Wonson of that city, half of which I have transmitted for these donors to the

museum of this Society and the other half to that of Dartmouth College. These specimens were brought from St. George's Bank, and were mostly from depths of about 40 fathoms.

By date of September 29, 1890, Professor Verrill wrote as follows, in reply to my inquiries concerning the Fish Commission collection of the fossiliferous bed-rocks of the Fishing Banks: "I have found it useless to try to work up the fossils till the recent shells from the same region are better known. We have already added more than 200 species to the list of the shells of the banks and their vicinity, and have many others on hand not yet described. Probably many of the fossils may be identical with these newly recorded or unrecorded species, but a very long and laborious study can alone determine how many are recent, owing to their imperfect condition." In the light of this lately added knowledge of the fauna of our submarine continental border[1], it seems very probable that these rocks will prove of Pliocene rather than Miocene age. Their uplift and subaerial erosion took place, therefore, as already indicated in the preceding part of this paper, at the close of the Tertiary era and immediately before the Glacial period.

The Fishing Banks are thus to be accounted, like the fjords of all our northern coasts, the submerged continuation of the Hudson River channel, and the similar very deep submarine valleys off the shore of California near Cape Mendocino, to which I have previously called attention[2], as evidences of a great epeirogenic uplift of the northern part of this continent preceding and producing the Ice age.

[1] Previous to 1870 the known molluscan fauna of the seas of northeastern America comprised about 290 species; but now, according to Prof. Verrill, it numbers 500 or more. In comparison with this we may note that the British Isles have about 600 species of marine mollusks, and the whole of Europe about 800. (Prestwich's Geology, vol. 1, p. 120-121.)

[2] "Probable causes of glaciation." Appendix of Wright's Ice age in North America, 1889, p. 573-595. Bulletin G. S. A., vol. 1. 1890, p. 563-567. Amer. geol., vol. 6, Dec. 1890, p. 327-339.

GENERAL MEETING, APRIL 5, 1893.

Vice-President B. JOY JEFFRIES in the chair. Fifty-five persons present.

The following papers were read:—

EVIDENCES OF MAN IN NICARAGUA DURING THE EARLY NEOLITHIC AGE AND THE PROBABLE PRESENT TRIBAL NAME AND LOCALITY OF HIS DESCENDANTS.

BY J. CRAWFORD.

Evidences of the existence of man along the western coast of Nicaragua, during the early part of the Neolithic age and probably in the Solutrian division of the Palaeolithic age, were discovered by the Spaniards early in the sixteenth century, without, however, any recognition of the great antiquity of the discoveries; and no description of them nor of the locality where found has been published.

They consist of:—

1. A few rough, chipped, arrow-heads and spear-heads of flint, jasper, or felsite.

2. Hard gneissoid rocks, about nine feet long, carved into representations of man — *i. e.*, stone statues of men.

3. Numerous fragments of pottery, made of clay, containing fragments of volcanic rocks, unadorned and originally unburned. Of these evidences, the most interesting and important, because having a reliable record as to the geological time or epoch in which they were made, are:—

a. Several well-executed stone statues found at the same locality and all of the same brachycephalic type, carefully and slowly sculptured, from blocks of hard rock, with brittle tools of flint, petrosilex, jasper, and felsite.

b. Oblong blocks of partly metamorphosed rocks about $3 \times 4 \times 9$ feet, in their natural state or but slightly shaped by man, some of them placed in alignment with the two parallel rows of stone statues and apparently forming the foundations for an oblong temple or observatory extending east and west. Other similar rocks were in piles near the latter, placed so as to form the walls that were in alignment with the stone images.

c. Fragments of unadorned pottery found near the stone images, cemented in the debris of a well-marked subsidence, all discovered in the small valley on the west face of the mountain island of Momotombito. No other works of aborigines, menhirs, dolmans, or mortuary stones, have been discovered on this island.

Locality. The Island of Momotombito is located about Long. 86° 36′ west and Lat. 12° 30′ north near the western termination of Lake Xocotlan (Managua)[1] and about twenty-seven miles east of the Pacific Ocean; from the observatory or temple at the top of the cerro there is an unobstructed view westward to the Pacific Ocean; the vapor-emitting, volcanic cone Momotombo (altitude 6,650 feet) is five miles southeast of the water line of the lake.

The summit of the mountain Momotombito is about 2,500 feet above the lake (about 2,626 feet above the Pacific Ocean) and has a cone-shaped base, about 9,000 feet in diameter, at the upper surface of the lake; it is composed of minerals that transformed into rocks and hardened slowly from hydrothermal, plastic, or viscous masses, which were elevated to their present or greater heights by forces acting *vertically* from beneath, but so slowly as to permit the crystalization of several of the minerals, and the cooling and contracting were so regular as to cause the jointing and division of the mass into cuboidal or parallelopipedal blocks, those at the surface generally measuring about 3 × 4 × 9 feet each; in some places, however, the blocks or masses are much larger and more irregular and have been turned upon the edge or end at various angles to about 60 degrees.

Geological evidences on the island and neighboring mainland exist[2] showing that the vertical elevation evolving this island was commenced in the Pliocene epoch and continued during the Glacial epoch until completed to at least its present size and altitude and that probably its vertical elevation was in response to the depressing weight of ice that accumulated in the Glacial epoch in Nicaragua on the Amerrique range of mountains[3] about forty

[1] For localities I use the oldest names of the aborigines in order to preserve them for future ethnological study.

[2] Described in "Cerro Viego and its volcanic cones in Nicaragua" before the Amer. assoc. adv. sci., at Rochester, 1892.

[3] This range of mountains is the southern termination of the "Cordilleras" in Nicaragua and is not synchronous with, but older than, the Cordilleras in Costa Rica to the south and in Honduras to the northwest.

leagues east of this island. It was never a volcano, although situated only four or five miles south of that subterranean fissure extending through western Nicaragua (over which all post-Mesozoic volcanic cones in Nicaragua are found) which probably once connected the extensive group of active volcanoes in Costa Rica with the similar group in Salvador; it has no volcanic crater nor vent, nor evidence that rock materials were extruded from it in a plastic condition (no trachyte, andesite, rhyolite, phonolite, or basalt) excepting fragments ejected from the volcano Momotombo that fell on it; when viewed, however, from a short distance it has the appearance of a volcano, and it is usually so designated by tourists.

A synclinal valley, the eastern part of which rises about 200 feet above the water in the lake, is on the western side of the island mountain Momotombito. This valley gradually widens, for a distance of about 4,000 feet, to the lake; the southern part of the syncline was filled during the Champlain epoch to above the general level on that side of the island by drift, volcanic ejecta, and debris deposited during a subsidence of the island; it is now hardened into a partly stratified mass of conglomerate. The northern and larger part of this syncline is "The Valley of Momotombito" in which were found the half-metamorphosed rocks sculptured with implements of flint or stone by artists living at an early date in the Neolithic age, together with numerous fragments of rough pottery made and used by the sculptors, small fragments of flint, felsite, and jasper, not natural to the island, but brought there by the workmen, broken and used by them, and found cemented with deposits of drift between some of the rocks.

Description of the works. Six stones that had been sculptured into portraitures of men were found in the valley of Momotombito; each stone was about 9 feet long, of which about 3 feet were set firmly in the rock floor of the valley, facing westward; they were arranged about 500 feet from each other in two lines about 200 feet apart, beginning about 500 feet from the margin of the lake and extending eastward up the incline of the valley to within about 200 feet of the western ends of the north and south side of the foundation walls of the temple or observatory in course of construction; and this structure — or its foundation — was about 300 feet long — east and west — and about 200 feet wide

from north to south. The images, especially the faces and heads, the natural lines, prominences and depressions of the human body, were carefully executed and skilfully developed. The work was well done, especially when we consider the early age at which it was performed, and it proves an observant, thoughtful, painstaking people, who at that date in man's history were capable of chiseling hard rocks into representations of men with only brittle flint, jasper, and felsite tools.

Evidences of geological age. The geological time in which the sculptors lived and worked is discovered by examining and comparing the four lines of deposits of drift, ejecta, and debris found encircling the mountain at different altitudes, and marking the limit of subsidence during each of four distinct oscillatory movements of subsidence and elevation, and also by a study of the synchronous deposits of fossils in the same zone a few leagues distant. The earliest deposit recording subsidence occurred during the early or middle part of the Champlain epoch anterior to the forming of the syncline on the western side of the island, and its drift, ejecta, and detritus are found in a line around the mountain, hardened into irregular or oval shaped, partly stratified areas, at an elevation of about 450 feet above the lake, and corresponding in altitude and synchronous with a large deposit of *Ostrea princeps* Wood found about forty miles southeastward.

The second sediment recording subsidence occurred during the latter part of the Champlain epoch and formed the syncline, filling the southern half of it with materials in part silt and loess and traceable at intervals in a zone around the mountain at an elevation of about 100 feet above the lake. That this subsidence was anterior to the works made by man in the valley of Momotombito is evident from the fact that some of the rocks which had been removed into the valley by man were piled up on and covered a part of this line of deposit.

The third ring of sediment encircling the mountain, half hardened by cementing materials and showing subsidence, was found at an elevation of about 40 feet above the lake; of this deposit crossing the valley of Momotombito no connected line can be observed now, nor is there any evidence of it at the stone images. Probably the men working at the temple or images had loosened it in the valley, and floods of rain had swept it into the lake, but it is easily traced on either side of the valley.

The fourth and latest evidence of subsidence is found at an altitude of about 25 feet above the lake, in loosely compacted or sometimes cemented deposits of drift, ejecta, and detritus,—generally in spaces and joints between upturned rocks. In the valley of Momotombito to the north of and near the lines of stone images, this deposit holds *numerous* fragments of coarse, unadorned, unglazed, unburnt pottery.[1] This circle of deposits was found to cross obliquely, at an angle of about 10 degrees, and in part cover some rocks that the sculptors probably had removed to between the lines of stone images. It was this subsidence of 25 feet occurring in the early part of the Terrace epoch, as shown on the mainland to the west, which flooded to an average depth of about 25 feet the entire valley west and southwest of Lake Xocotlan to the Pacific Ocean, and which caused the sculptors and architects to abandon their work and seek security from floods and from volcanoes in the nearest and most accessible non-volcanic range of mountains, namely, the *Amerrique Range*, about forty leagues to the east of the Island of Momotombito.

The type of man to which the sculptors belonged. These artists most probably had for models some of the eminent men of their own people, and had no knowledge of other types of man; consequently they represented in these statues, a type of large, well-formed man, above the average height, with large mammae on a well-expanded chest, head distinctly brachycephalic, forehead prominent and high. The heads appear to be represented as slightly compressed anterio-posteriorly, but no dolichocephalic features are indicated. The man represented by the sculptured stones found in the valley of Momotombito, resembles more nearly the Polynesian-Mongolian than any other race, and we probably have in these sculptors and the models for their stone images, a Polynesian or modified Mongolian type of man, about six feet high, of large and strong frame, and distinctly brachycephalic, a people of such intellectual development that they could patiently for many months or years continue their work, and who studied, obtained, and retained such distinct and true impressions of the human form and features, as to be able to present them in hard rock, in carefully chiseled outlines, using only rough flint and felsite tools. These artists, judging from their works, were far superior in intellectual attainments to any of the Indians and to a large per-

[1] This pottery was carefully sun-dried but not hardened by fire.

centage of the lower and even of the middle classes of Latin-Americans now (1892) living in Nicaragua, excepting possibly the Amerrique people who live on the east side of the Amerrique range of mountains in south-central Nicaragua.

Evidences as to the tools. That the sculpturing was done with stone and flint tools is shown by three facts: (1) Fragments of these were found wedged or forced into some few vesicular cavities in remnants of two of the images; (2) No flints nor felsites are found elsewhere in cavities nor in surface deposits on the island; (3) No metallic oxides nor metallic oxide stains (*i. e.*, no evidence of metallic tools) were discovered in any rock examined at the works. The rocks were probably saturated with water while the sculpturing was in progress, because small druses of quartz were found in cavities in two of the rocks that had been worked on by the sculptors. The flint, jasper, petrosilex, and felsite for making the tools, were obtained either from a valley on the mainland distant about six leagues from the stone statues, on the Island of Momotombito; or from the side of Cerro Tablone, about 14 leagues to the southwest and within two leagues of the Pacific Ocean where rough chipping of flints and stone arrow-heads, spearheads, etc., probably of Solutrian age, exist. These are the only localities in that part of Nicaragua where flints, jaspers, chalcedonies, novaculites, and felsites are found.

The clay of which the pottery found with the stone images was made was most probably obtained about five leagues west, on the mainland, at a locality now known as PUEBLO NUEVO, the only place where such clay is found within a radius of about twenty miles. The Indian women now living there make cooking utensils, osiers for water, etc., and sell them in the city of León, eight leagues west of Pueblo Nuevo.

Whither the sculptors and architects and their people migrated; their probable descendants. The submergence of twenty-five feet of the Island of Momotombito would have also submerged to a greater depth all the plains and land west and southwest from the island to the Pacific Ocean, except the small Cerro Tablone, about 14 leagues to the southwest, and a few knolls and ridges, and the volcanic cones and masses to the southeast, south, north-west and north of the island, and would have caused the people living there to seek safety from the storms and waves of the Pacific Ocean. A subsidence of western Nicaragua to a depth of

twenty-five feet would inundate all the subterranean volcanic caverns in that region, and the water coming into highly heated fissures and caves would cause terrific explosions and violent expulsions of volcanic bombs and the extrusion of large quantities of fused aqua-igneous materials, and would thus compel animals of all kinds to hastily seek refuge at the most accessible locality.

The synchronous activity of all the volcanic masses and cones in western Nicaragua is well marked on the mainland. Some of the extrusions yet remain, in small areas, at several places between rocks, to a depth of three or four feet, on the Island of Momotombito, but the greater part of the ejecta which fell on the island has been removed by rain floods.

In the face of such catastrophies — subsidence, floods, and volcanic activities — the sculptors and their people would have moved eastward, across Lakes Xocotlan and Nicarago (Nicaragua) to the verdure-covered Amerrique range of mountains visible from Momotombito.

A striking similarity exists between the type of man represented in the stone images discovered in the valley of Momotombito and the form and features of the Amerrique people[1] now living on the eastern side of the Amerrique range of mountains. The small stone images discovered at San Pedro de Lobado (four leagues south of the southern end of the Amerrique mountains) closely resemble the large stone images discovered on the Island of Momotombito; the former are claimed by some of the Amerrique people to have been sculptured by their ancestors, at the time (very long ago, they say) when their people also occupied the valley of San Pedro de Lobado and southward to the Rio Rama, within a few miles of the route selected for the Nicaraguan Interoceanic Canal.

There exists a striking resemblance between the stone images made in the valley of Momotombito, those made at San Pedro de Lobado, the Amerrique people, the Chibehas and Muyscas (in western South America), and the Polynesians, and all these are quite different from any other people or the works of their ancestors, yet discovered in South, Central, or North America. There is a quite clear resemblance between the sessile stone images found near the northern end of the volcanic island of

1 Not pure Indians although generally so designated; apparently modified descendants of the Mongolian type.

Ometepe in Lake Nicarago[1] and those discovered in the valleys of Momotombito, and those of San Pedro de Lobado. The stone images discovered on the Island of Ometepe resemble the works of the ancestors of the Muyscas and Chibehas so closely that they were probably made by descendants of the Chibehas and of the sculptors of the stone images discovered on Momotombito. Certain eminent geologists believe that previous to and during the Glacial epoch a land connection, or two chains of islands with narrow oceanic intervals, existed between Polynesia and South and Central America (including the state of Chiapas in Mexico); confirmatory evidence of this land connection is afforded in the resemblance between the recently discovered marsupial and other mammalian fossils found in Patagonia[2] and those found in Australia. Other geological facts also point to a time when a land communication existed between all the southern continents; and some ethnologists claim to have discovered symbolic and linguistic relations of a close character between aborigines on the west coast of both Central and South America and Polynesia.

From the foregoing it is quite probable that the aborigines of the sculptors of the stone images found on the Island of Momotombito, came from Polynesia, over the land route or chain of almost connected islands then existing across the Pacific Ocean, and that the latest subsidence of twenty-five feet, as recorded on the Island of Momotombito and the western part of Nicaragua, and the consequent synchronous activity of all the volcanoes in that region, both occurring during the time when the sculptors were carving stones into images of types of their own people, caused the sculptors and their tribe to migrate eastward (the only safe route) and seek a home on the side of the very fertile and non-volcanic Amerrique mountains, where their probable descendants — the Amerriques — now reside.[3]

Several interesting facts are known to have occurred in the history of this Amerrique people.

[1] See Dr. J. F. Bransford's excellent Archaeological researches in Nicaragua in the Smithsonian contributions to knowledge, v. 25, 96 pp., 2 pl., 135 cuts, 1881.

[2] See Dr. Florentino Ameghino's paper published in 1891 in El revist. Argent. hist. nat.

[3] This locality and people have been described by the late Thomas Belt in his book "The naturalist in Nicaragua," London, 1867. Second edition, revised and corrected, London, 1888.

1. In the archives of the Episcopal palace in the city of Leon, Nicaragua, records exist of the baptism about A. D. 1680 (date indistinct) of the chief of the Amerriques (the Chontals were a division of the Amerriques occupying adjoining territory) and of his marriage with a young Spanish woman.

The history of the conversion to Christianity and marriage as related by some of the descendants, now residing at Juigalpa, Nicaragua, is that a sister of the chief was taught letters and Christian principles by the young Spanish woman. The two became much attached to each other and the Amerrique invited the Spaniard to make her a visit at the city of the Amerriques, across the mountain, about thirty miles to the eastward. The invitation was accepted, but the Spanish residents at Juigalpa prevented the visit, and in such a way as to offend the chief of the Amerriques, who attacked the town, killed many of the Spaniards, and captured the young girl, the friend of his sister. By kind treatment he persuaded her to consent to marry him; this she agreed to on condition that he would go to the city of Leon, and there be baptized into the Christian faith, and be married by the Bishop of the church. The records relate that they arrived at Leon[1] accompanied by about five thousand Amerriques (called Chontals in a part of the description) where the baptismal and marriage ceremonies were performed.

2. In September and October, 1502, a number of the Amerriques met and remained with Christopher Columbus at the harbor of Bluefield, each of the Amerriques *wearing a "mirror of gold"*[2] (see "Litra ravissamo"), and they, Columbus and a part of his 150 mariners in search of gold, ascended for about sixty miles the Rio Bluefields (Escandido, Spanish; Rama or Carca, Indian) to the long series of cascades found in each of the three rivers, the "Rama," the "Mico," and the "Carca" or "Siquia," which at the foot of the cascades unite and form the Rio Bluefields. The locality is now known as Rama, and a small town was recently built there; about eighty miles further westward from the

[1] The old city of Leon, about eight miles west from the island of Momotombito, now known as the railroad station Momotombito, is situated on the west side of Lake Xocotlan, at the foot of the volcano Momotombo; it was destroyed by an eruption from that volcano about 1720.

[2] Prof. Jules Marcou, in several publications, contends that it was the Amerrique people of Nicaragua who met Christopher Columbus in 1502 and from whom the name AMERICA was derived.

town of Rama was the principal town of the Amerriques, situated on the eastern foothills of the Amerrique range of mountains, where placer mines containing gold and lodes rich in gold are found.

Note: — The six stone images described in this paper have been disposed of as follows: —

Two of them are 953 and 954 in the collection of prehistoric anthropology in the Smithsonian institution. Early in 1892, under the direction of the author of this paper, three others were removed from the Island of Momotombito to the city of Leon, Nicaragua. Two of these are to constitute a part of the Nicaraguan exhibit in the World's Columbian Exposition at Chicago in 1893. The other complete and in good preservation was promised in July, 1892, by President Roberto Sacasa of Nicaragua, to Hon. Señor Senador Doctor T. Tigerino of Chinandego, Nic., for the Peabody museum at Cambridge. The other was broken and the head, it is reported, sent to Philadelphia.

Note by Jules Marcou.— This paper by Mr. Crawford, giving an account of the great antiquity of the men who sculptured and chiseled hard rocks into representations of men with only flint, jasper, and obsidian tools, is, on account of his careful geological observations in the valley of Momotombito, the most important yet published.

Half way between Central America and New Zealand, at the very small Easter Island, the numerous stone images show that a land route existed, in Quaternary times, across the present Pacific Ocean. The learned M. Alphonse Pinard, explored Easter Island in 1877, finding, in the valley of the Roronoraka volcano, forty stone statues or images, worked out of trachytic rock. In digging there he found at some depth a quantity of stone obsidian implements, which were used in cutting and polishing the images or statues. Stone images of colossal size, as many as eighty at a single place, have been found at other places on the island. (Exploration de l'île de Pâques, Bull. soc. géogr., Paris, Sept., 1878, p. 193.)

The sculptors of the stone images occupied a very wide area from Central America, Peru, Bolivia, and Chili to Easter Island, New Zealand, and Tasmania. As to their original place, it is difficult to give a positive opinion; they may have come from Polynesia as Mr. Crawford is inclined to think, or they may have

migrated from Central America and Peru westward to Easter Island and Polynesia. Everything now points out that continental areas existed during Quaternary and even Tertiary times in the southern regions of the globe, and that the existing faunas of Madagascar, Tristanda Cunha, Kerguelen Land, Campbell Islands, New Zealand, Easter Island, the Galapagos Islands, Juan Fernandez, Tierra del Fuego, and of southern America came from great continental surfaces. Subsidences have left only islands and the western parts of South America and Central America as witnesses of periods of time and of inhabitants which passed away at the end of the Quaternary epoch.

BIOPLASTOLOGY AND THE RELATED BRANCHES OF BIOLOGIC RESEARCH.

BY ALPHEUS HYATT.

Scientific conservatives to whom new terms are distasteful will, I fear, find little that is praiseworthy in this paper. Those who lift their voices in protestation against the multiplication of terms carefully worked out and founded upon observation are wasting time that they might employ to better advantage impartially testing their truth and discussing their applicability and utility. Science has invariably marked its progress with new names and new terms; these are the mile stones and finger posts; he who does not know how to use them cannot get along as fast as he who does.

The same struggle exists in taxonomy between the old school desiring the old generic names to be retained and those who are dividing and subdividing accepted genera into new genera in accordance with the results of observation. As a rule the new subdivisions eventually gain admission to the literature. The older men of each generation as a rule reject them, but the younger test them without prejudice, and, if they are useful, as they commonly are when founded upon thoughtful observation, wonder why any one refused to make them a part of the vocabulary of science.

This has been the fate of the terminology proposed and the ideas published by Haeckel in his great book "Morphologie der orga-

nismen" and the efforts of the author in a limited part of the same field. Luckily the younger men, who have since tested the methods of work proposed at that time and considered them worthy of their adoption, have so far found ground for serious criticism only in the nomenclature.

It would be too sanguine to expect these beatific conditions to last, but in the meantime those who agree upon the main ideas and objects of the new school ought to be able to reach common ground upon the less important details of nomenclature. With the view of doing my part towards this desirable end I have written the following paper partly in reply to a critical paper by Messrs. Buckman and Bather and partly as a new contribution in the same field.

I propose to describe in a brief way the four different lines of research which are usually designated by the popular terms growth, heredity, acquired characteristics, and the correlations of development of the individual (ontogeny), with the evolution of the group to which it belongs (phylogeny) ; the object being to explain the relations of these to each other and to give adequate reasons for the substitution of scientific terms for the popular names heretofore used. Since I have to refer to one of the new names before the explanation appears in the text, it is proper to state that, instead of the study of growth, it is proposed to use the term auxology or bathmology ; for heredity, genesiology ; for the origin of acquired characters, ctetology ; and for the correlations of ontogeny and phylogeny, the term bioplastology.

Auxology or Bathmology.

Messrs. Buckman and Bather, both well known for their original and instructive researches in paleozoology in England, have recently in a joint paper under the title of "The terms of auxology"[1] justly criticised the nomenclature employed in my papers to designate the stages of growth and decline in the individual. They have also proposed, in view of the correlations which have been shown to exist between the transformations that occur in the stages of development and decline in the individual and those that characterize the evolution of the group to which it may belong, to designate the study of these correlations by the new term "aux-

[1] Zool. anz., 15, p. 420–421, 429–432, November, 1892.

ology." This term is open to the objection that it is derived from αὔξη meaning simply progressive growth up to and including the adult stage, and although in common with others I have felt that it has claims to be retained, there are good reasons why it should be more restricted in application.

I have placed two terms at the head of this chapter partly because I have not had time to consult the proper judges, physiologists, and obtain their decision, and partly because I am undecided in my own opinion. Cope in his "Method of creation of organic forms"[1] used the term bathmism from βαθμὸς, meaning a step or threshold, to designate growth force, and it is therefore questionable whether the term bathmology should not be substituted for auxology in order to give uniformity to the nomenclature.

It is not necessary to discuss this here, and the facts are merely mentioned to call attention to this question and bring out expressions of opinion. Physiologists and naturalists universally recognize that essential distinctions exist between growth and development of organisms.[2] Herbert Spencer in his "Principles of biology" gave these differences with great clearness. He pointed out that, as a general conception, the definition of growth, increase in mass, is applicable in different ways to all the bodies that have arisen through evolution. Physiologists understand the science of growth to be an inquiry into the laws that govern the increase or reduction of the body and its organs in bulk. Development, on the other hand, is defined by Spencer as follows: "By development, as here to be dealt with apart from growth, is meant increase of structure as distinguished from increase of mass."[3]

Cope has given a more thorough analysis of the same processes in his "Origin of the fittest" (Preface, p. viii), as follows:—

1. The law of repetitive addition, in which the structures of

[1] Proc. Amer. phil. soc., v. 12, p. 229–263, Dec. 1871; also Origin of the fittest, p. viii.

[2] The word development is often loosely used for increase of bulk by growth, thus "the development of an organ" is often spoken of when its growth is meant as well as its increase in characteristics. By development is here meant the results of growth and heredity as distinguishable in the increase of characteristics and differentiation or the decrease of characteristics and retrogression.

[3] The principles of biology, v. 2, p 440, Amer. ed. 1872.

animals were shown to have originated from the simple repetitions of identical elements.

2. The existence of an especial force which exhibits itself in the growth of organic beings, which was called growth force, or bathmism.

3. That development consists in the location of this energy at certain parts of the organism.

4. That this location was accomplished by use or effort, modifying and being modified by the environment, or the doctrine of kinetogenesis.

5. That the location of this energy at one point causes its abstraction from other points, producing "complementary diminution" of force at the latter.

6. That the location of this energy, so as to produce the progressive change called evolution, is due to an influence called "grade influence."

7. That inheritance is a transmission of this form of energy, which builds in precise accord with sources from which it is derived.

8. That this "grade influence" is an expression of the intelligence of the animal, which adapts the possessor to the environment by an intelligent selection.

It will be seen further on that most of the conclusions are very similar to the views taken in this paper, but I have not yet been able to understand or use the idea of "grade influence," or recognize the need of this to the explanation of the phenomena of serial gradation. I also separate bathmism from heredity because the location of characteristics and the phenomena of inheritance, generally from my point of view, appear to exhibit a mode of action entirely distinct from growth and therefore requiring the assumption of a different force from that which sustains and governs growth.

Dr. C. S. Minot, who has given the first demonstration of the fundamental law of growth, has shown[1] that the common views with regard to the action of this force in organisms are erroneous. His plotted curves of the actual additions of bulk, by growth during equal intervals of time in guinea pigs show that these increments are in a steadily decreasing ratio to the weight of the

[1] Senescence and rejuvenation, Jour. phys., v. 12, p. 97–153, 1891, and On certain phenomena of growing old, Proc. Amer. assoc. adv. sci., v. 39, p. 271–289, 1890.

animal from a very early age. He was so much impressed by these facts that he characterized the whole life of the individual as a process of senescence or growing old.

Although this term seems to be defective, since the word senile has an accepted popular and scientific meaning and an appropriate application in morphology to a distinct period of ontogeny, Dr. Minot's facts are no less significant and show that we cannot make any distinction between the progressive and retrogressive or senile stages of the development of the individual in terms of growth force. Growth is essentially a constantly decreasing force even in the progressive stages of development. In other words increase of bulk, and development as manifested by the addition of characteristics, are more antagonistic than has been supposed. The increase in the bulk of the body by fission of cells and, even as stated by Minot, the increase of cytoplasm around the nucleus of the cell itself, must be regarded as a load upon growth force. This force according to Minot can be measured by the proportionate amount of nuclear substance, which is largest in the cells at a very early period of development and then constantly decreases with age in proportion to the elaborated cytoplasm.

Naturalists have, as a rule, understood the differences between the organic molecular increase that takes place within cells, which is the simplest form of growth, and that which follows this and builds up the tissues of the body by the division of cells. Both of these processes although distinct from each other result in additions to the bulk of the organism and come properly under the head of growth. But while both are thus constructive so far as the body is concerned, only one can be considered constructive or anabolic, while the other is essentially destructive or catabolic, so far as the cell itself is concerned.

The cell grows by internal additions and this process builds it up, but when the differentiations which lead to subdivision begin in the nucleus and cytoplasm, this is as purely the development of characteristics by the breaking down and specialization of the parts of the nucleus as is the subsequent fission or breaking down of the cell itself to form daughter cells. Nevertheless, so far as the increase of the bodies of Metazoa is concerned, the latter is substantially a constructive process. The process of growth is therefore first the anabolic increase in size of the cell itself by the assimilation of foreign materials, second the breaking up or

catabolic differentiation of the cell structure, and third the fission or division of the mother cell into daughter cells. Then this cycle repeats itself by the aid of nutrition and assimilation which furnish the materials for further anabolism and catabolism.

The multiplication of cells of course adds to the number of nuclei and therefore adds to the sum of growth force in the body. In other words, each new nucleus is an additional center for the assimilation of food and storage of energy which is subsequently used in developmental catabolism leading to the formation of new centers of storage and distribution. But this increase as stated above is working at constantly increasing disadvantage owing to the still greater proportionate augmentation of the load, or in other words, of the products of the work done by the nuclei.

Minot's researches and those of Maupas, as well as the general phenomena of old age, make it very probable that there is also, in consequence of use and wear, either an absolute decline or decrement of force and mass in the nucleus itself taking place very gradually and visible externally only when it has become general and affects the existence of some function or occasions the decrease in size and loss of some organ or part, or the degeneration of the whole body in extreme cases of senility.

If the nuclei were in constant ratio to the amount of cytoplasm in the cell, there would be no optical confirmation of these remarkable observations. But Dr. Minot is able to add that the nuclei of cells present precisely the metabolic changes that one would expect to find in them if they were centers of the assimilative and reproductive powers of the body. In the young cells of guinea pigs the nuclei are very large as compared with the surrounding cytoplasm, and then diminish with age in proportion to the mass of this cytoplasm.

In Maupas's researches also the ultimate generations of the agamic cycle were found to pass through transformations in which they decreased in size, and the micro-nuclei also degenerated and became unfit for conjugation. Thus, in spite of additions to the number of the colony caused by the multiplication of protozoans, the additions to the power of growth as indicated by the size of the nuclei are proportionately on the decrease. There are of course other factors when the cells remain together and form a body as in Metazoa or a permanent colony as in some Protozoa. They necessarily become loaded by the development of various kinds of

secondary products characteristic of the structures of the body or the colony, and beside all these the sum of the load is continually acted upon by gravity which increases directly as the mass, while the strength of the materials remains more or less constant.

Multiplication by fission among Protozoa beginning with a single zoon, as has been shown by Maupas, may reach through many generations, but finally they die out unless reinforced by conjugation with another brood. These broods or disunited colonies, according to Maupas's observations, live and die collectively like the more complex and closely united colonies of cells making up the individual among Metazoa, and thus the growth and development of cells in the latter and the free adult agamic generations of the Protozoa are, so far as we know, precisely parallel and both are ontogenetic. Agamic reproduction by fission alone is in other words a process of limited power extending only through a certain number or cycle of generations of cells in all forms, and so far as known dependent for its perpetuation and renewal in all organisms upon some form of conjugation. Cellular division, although distinct from the fissiparous modes of reproduction occurring in the building up of colonies of zoons in more complex organisms, Hydrozoa, Actinozoa, and so on, has nevertheless a similar result in so far as it multiplies the numbers and adds to the mass if the daughter zoons remain connected or to the number of generations if these separate and become individualized.

It is of course not intended to ignore the great differences that exist between the separate generations of any organic process of multiplication and those that remain attached and form colonies or masses but merely to show that they agree in certain respects.

The restoration of lost parts or organs dependent upon the multiplication of cells is so intimately related to all forms of hypertrophy and to asexual budding that these, in so far as they increase the masses of tissue, are properly considered as part of the phenomena of cellular development.

Those forms of gemmation which give rise to distinct zoons[1] are

[1]This word was used in my "Larval theory of the origin of cellular tissue," p. 46, as a parallel term with "phyton" among plants, meaning in the animal kingdom any form having typical structure of its own group or the elements of those structures. This is accurate in application to the Metazoa, but in speaking of a protozoan as also a unicellular zoon I went too far. A metazoan is also a multicellular zoon or metazoon; a sponge

in accordance with the principles of bioplastology equally additions arising from organic cellular reproduction and consequently properly included under the same heading, and in this category parthenogenesis should also be included. All of these are essentially differentiated modes of forming colonial associations of zoons which are either parts of simple or complex cycles. They correspond to Huxley's individual which is defined by him as the whole product of one egg. Such cycles of independent beings are naturally included under the terms of growth since they are in no sense due to rejuvenescence produced by conjugation, but like the independent generations of Infusoria observed by Maupas represent when collectively considered cycles of development, usually having first asexual zoons unable to perpetuate themselves by conjugation, then sexual zoons, and then either these or their descendants or associated modified forms present the degenerative extreme of the cycle.[1]

If, now, the Haeckelian terms anaplasis for the young and adolescent stages, metaplasis for the adult, and the term used farther on for senile stage, paraplasis, be adopted, it is obvious that the term growth applies only to the connections that exist between these three ages and the building up and decline of the agamic cycle. In other words the branch of science dealing with growth is essentially ontogenetic. Over and above the physiology of cellular metabolism, it can also be appropriately applied to the morphology of intra-cellular increase or anabolism, and cellular development or catabolism, and the phenomena resulting from the alternating

is a zoon of the Porifera or a spongozoon, but it is confusing to use "zoon" for a single protozoan. This is morphically a free cell and in allusion to the common mode of multiplication I have descriptively styled it an autotemnon. Thus a single free protozoan is an autotemnon and also its descendant from the single tissue cell in the metazoan, but the colonies of Protozoa such as those studied by Maupas, or those held together as in Vorticella, are alone comparable with a zoon of the Metazoa. Individual even if defined in a very broad sense, means an independent being that cannot be artificially divided without at least the temporary loss of its individuality and is sometimes used in a modified sense even for inorganic bodies. Person as used by Haeckel and others is equally objectionable since it can be properly applied only to individuals having a certain character. The personality of God or of a man is an appropriate expression but the personality of a polyp conveys an essentially erroneous idea so far as our existing knowledge of such animals extends. Zooid can also be used in connection with zoon but it is somewhat less definite, meaning really, like a zoon.

[1] See remarks on Maupas's researches below under "The cycle."

action of these whether occurring in the single metazoon or colonies of metazoons or the autotemnon (single protozoon or tissue cell) or in the organic cycles of these organisms.

When one passes beyond this and attempts to deal with the characteristics of ontogeny, he at once finds himself in the presence of other forces, such as heredity and other processes, namely, the acquisition of new characters and the renewal of the powers of nuclear substance by means of conjugation, whether this occurs between agamic autotemnons as stated by some authorities or between those that may be distinguished as gamic by their supposed sexual differences, or between true zoons that are known to be sexually distinct.

The laws of growth, in other words, deal with all the problems that flow directly from the union of the two factors, suitable food and a living organism, and the form of energy generated in this way.

Genesiology or Heredity.

The term heredity has been used in two senses, one expressing the results of the action of an unknown force which guides the genesis of one organism from another, and a second in which it implies the force itself. C. Herbert Hurst[1] has pointed out the confusion of ideas which prevails in the usage of this term in his "Evolution of heredity," and I quote from him the following: "The schools of Pangenesis and of Continuity [Weismannian] alike regard heredity as the original and normal course of events, and variation as a secondary and abnormal occurrence brought about by the fortuitous interference of some extraneous influence. Even modern text-books speak of 'heredity' and 'variability' as if they were concrete entities capable of producing effects. One would laugh at the philosopher who sought to explain the turning of a weather-cock to the south-east on a particular occasion by referring it to the bursting into activity of a long-latent tendency to turn to the south-east. The 'tendency to vary' and the 'phylogenetic force' of some writers, the 'force of heredity' and 'force of variability' of others, are

[1] Natural science, v. 1, p. 579, October, 1892.

equally absurd. T. J. Parker says[1] '*Heredity* . . . is modified by *Variabilty*' and earlier writers are not less slip-shod in their treatment of these and allied subjects."

Clearness demands that some other term than heredity should be used and I consequently propose to designate the study of the phenomena by the term GENESIOLOGY from γένεσις, meaning that which is derived from birth or descent. This force itself is a genetic force, and the principle of heredity thus becomes genism. Hurst's papers, although they treat the history of genesiology as if Haeckel, Darwin, and Weismann were the only authors worthy of quotation, are extremely suggestive and the facts of paleontology are in accord with some of his theoretical assumptions. The neglect of paleontology has weakened his arguments as it has the various similar essays founded exclusively upon the observation of existing organisms. One can agree with his conclusions that "heredity is merely a likeness of effects due to the likeness of the causes producing them" and that "heredity is essentially a limitation of variation" and also "that if no such phenomenon as heredity occurred in early stages of evolution it would of necessity arise by degrees through the action of well-known influences, and without the intervention of any unknown force or gemmule," and yet be perfectly consistent in regarding heredity as the exhibition of a different process from growth and of a different although probably secondary form of growth force, as it is very commonly supposed to be at the present time.

Mr. Hurst does not seem to have given full weight to the process of conjugation and consequent rejuvenescence which does not occur except through the union of distinct autotemnons and zoons and could not occur if this process was not very different from all others that produce an increase of mass. He also neglects noticing that in the case of asexual generation by fission the end is the establishment of new centers of assimilation and storage of energy. In the latter case the occurrence of likeness is inevitable and not so far removed from the division of a homogeneous substance that we need feel puzzled that one protozoon or cell generated by fission is like its twin companion and must pass through similar stages of growth.

[1]"Elementary Biology," 1891, p. 145.

The phenomenon of karyokinesis has not been ascertained to be universal and its complexity indicates that there are, or have been, simpler forms of this process. In fact it is positively known that fission may occur by the direct process of division or amitosis and this has been observed in the retrogressive stages of cellular division so that it is at present supposed by some to be degenerative and to occur only after the cell has passed through its karyokinetic or mitotic stages.

This shows clearly that one cannot assume with certainty that normal reproduction by fission in the simplest Protozoa must be considered as taking place by the same complicated processes as those observed in the Infusoria. If the cycle exists in Protozoa as can be reasonably assumed from the phenomena of metabolism and the observed degeneration of the nuclei, then one ought to anticipate the discovery of some simple mode of cell multiplication among the more generalized forms corresponding more or less remotely to the amitotic degenerative mode.[1]

Whatever the fate of this prediction, it is quite certain, so far as known, that the continuity of the same elements in the natural division of cells makes it comparatively easy to explain the transmission of likeness, but when that process becomes complicated with the effects of the conjugation of two organisms, the difficulties increase until finally in the bodies of the Vertebrata they culminate in a problem of surpassing difficulty. In these the ova and spermatozoa are extremely minute and yet through them must have come in endless procession all of the thousand of characteristics and tendencies derived from the immediate ancestors and also many others descended through a chain of unknown length from ancestors of unknown antiquity. Putting the camel through the eye of the needle does not state the physical difficulties adequately.

Every purely corpuscular theory, meaning thereby the physical transmission of gemmules, biophors, pangenes, or any other supposed organic bearers of characteristics, must not only account for a difficulty as great as that of the camel and the

[1]After this was written I found Johann Frenzel's paper, "Die nucleolare kernhalbirung" (Arch. f. mikr. anat., v. 39, p. 1–32, 1892), in which he claims that the amitotic process is followed by the multiplication of cells in certain cases among the Invertebrata and refers to Schultze's Rhizopodenstudien, V. (Arch. f. mikr. anat., v. 11, p. 583–596, 1875) to show that the same process has been observed in Amoeba.

needle's eye, but must also account for putting the numberless characters derived from the entire caravan of its immediate progenitors and remote wild ancestors and their progenitors back to the origin of their phylum, through the same narrow tunnel. This physical difficulty is still further enhanced by the fact that the ova and spermatozoa do not increase in size in proportion to the increasing number of characters transmitted.

One has to imagine the corpuscles and all this active circulation and concentration taking place invisibly and yet requiring visible vehicles of transmission in the minute spermatozoon and nucleus of the ovum. Then he must picture their redistribution over the body of the offspring, the larger number remaining latent until the proper time arrives for them, and then locating themselves and coming out in exactly the right place, or repeating at the right time some tendency or habit of the ancestors. These appalling difficulties rest upon an original assumption that has to be propped up by a series of secondary hypotheses, not one of which offers a single visual fact to justify its invention.

Granting the existence of gemmules, biophors, or pangenes, is a mental process that places the whole history of organisms outside of the laws of motion that have been observed in all inorganic bodies. It makes the entire phenomena of evolution depend upon the shooting out of a mass of organic small shot from the primitive protoplasm of the earliest times, with a force as inconceivable as are the ways and means of their transmission, to the targets in the ova and spermatozoa of existing animals. All of this is asked upon the ground that some form of gemmule must exist because this is the only mode in which characteristics can be transmitted.

So far as I can ascertain, the supporters of corpuscular theories do not seem to be aware that there is another imaginable hypothesis worthy of their attention, or at any rate do not discuss any other. Nevertheless there is one now over twenty years of age which has been supported by eminent naturalists and which has strong claims to serious consideration.

Ewald Hering[1] was the first to maintain the close similarity between the functions of memory and heredity, and to try to

[1] Ueber das gedächtniss als eine allgemeine function der organisirten materie. Wien. Almanach, v. 20, p. 253–278, 1870; Arch. sci. phys. et. nat. Genève, v. 40, p. 190–192, 1871. Translated in The open court, Chicago, v. 1, nos. 6, 7, 1887.

show that they were probably identical. Haeckel[1] maintained the same dynamical hypothesis, and Professor Cope, who has been the originator and consistent supporter of dynamic theories in this country, has insisted upon the truth of this hypothesis in two essays[2]; the following are quotations from the latter, "On inheritance in evolution."

"If the doctrine of kinetogenesis be true, this energy [the building energy] has been moulded by the interaction of the living being and its environment. It is the expression of the habitual movements of the organism which have become impressed on the reproductive elements. It is evident that these and the other organic units of which the organism is composed, possess a memory which determines their destiny in the building of the embryo. This is indicated by the recapitulation of the phylogenetic history of its ancestors displayed in embryonic growth. This memory has perhaps the same molecular basis as the conscious memory, but for reasons unknown to us, consciousness does not preside over its activities. The energy which follows its guidance has become automatic, and it builds what it builds with the same regardlessness of immediate surroundings as that which is displayed by the crystallific growth energy. It is incapable of a new design. . . . . It appears to me that we can more readily conceive of the transmission of a resultant form of energy of this kind to the germ-plasma, than of material particles or gemmules. Such a theory is sustained by the known cases of the influence of maternal impressions upon the growing foetus. Going into greater detail we may compare the building of the embryo to the unfolding of a record or memory, which is stored in the central nervous organism of the parent, and impressed in greater or less part on the germ-plasma in the order in which it was stored. The basis of memory is reasonably supposed to be a molecular (or atomic) arrangement from which can issue only a definite corresponding mode of action. That such an arrangement exists in the central nervous organism is demonstrated by automatic and reflex movements."

1 Die perigenesis der plastidule oder die wellenzeugung der lebenstheilchen. Berlin, 1876.

2 Amer. nat., v. 16, p. 454–469. 1882; reprinted in the "Origin of the fittest," p. 405-421, and "On inheritance in evolution," Amer. nat., v. 23, p. 1058–1071, 1889.

Although Ribot's work on "Heredity"[1] has not been widely read or accepted by scientists, perhaps because he admits as substantial evidence many facts which have not been verified, it is nevertheless by far the most profound work on this subject that has been published. This learned authority after careful investigation came to the same startling conclusion that memory was the only function of organisms which could be closely compared with heredity, and he brings forward a large number of facts to which many others can easily be added. He says "heredity, indeed, is a specific memory; it is to the species what memory is to the individual. Facts will hereafter show that this is no metaphor, but a positive truth."

Any naturalist who has studied the sudden recurrence of habits in animals, usually accounted for by the use of the meaningless term instinct, will find that this is no figment of the imagination but a working hypothesis that may be used and tested.

The authors quoted above have not discussed memory, as has been commonly supposed by naturalists, in a metaphysical sense, but as an organic function arising from voluntary or involuntary repetitions of conscious or unconscious actions. Ribot indulged in general speculations and was hampered by them to a notable extent, but he struck the key note of the dynamical theory of evolution. Thus he says: "Every act leaves in our physical and mental constitution a tendency to reproduce itself, and whenever this reproduction occurs the tendency is strengthened; and thus a tendency, often repeated, becomes automatic. This automatism is the link between memory and habit, and gave rise to the saying that memory is only a form of habit—a proposition which, with some restrictions, is true."

Repetition or the reproduction of parallelisms is equally characteristic of memory and of heredity, nor can either be conceived of as having a tendency to produce variations. It is entirely reasonable that any newly acquired habit, due to conscious effort or to the involuntary reactions of organisms in the presence of external stimuli, may be regarded as one of the products of memory. It follows from this, that any structural modifications which may result from the repetition of the same acts or habits, can with equal reason be attributed to memory. The tendency of descendants to perform the same action, *i. e.*, to manifest the same habit

[1] Heredity, Translation, New York, 1876.

in the presence of similar stimuli, when no special structure has been originated, can thus be readily accounted for if one considers heredity to be one form of organic memory.

When special structures have arisen through habit the reappearance of these structures in descendants at the same time or earlier does not present the same difficulty that it seems to place in the path of other theories. On the contrary, this is one of the strongest confirmations of what may be called the mnemogenic hypothesis of heredity or mnemogenesis.

In mnemonics it is the machine-like regularity of the succession of cause and effect, of one word begetting the next, that surprises the student, the recurrence in the mind of long forgotten words, languages, and scenes, either in the recurrence of some inciting cause or upon the removal of interfering causes, as in the recurrence of youthful reminiscences in aged persons. Mnemotechnics as embodied in the various systems which have been devised to cultivate the memory consists essentially in the habit of forming a chain of associated ideas or words leading up to the word or thought to be recalled.

If characteristics were inherited irregularly there would be no parallel between the functions of memory and heredity, but the precision of the succession of hereditary characters in the development of the individual is precisely in accord with the theory of mnemogenesis.

Even reversions that may be supposed to be purely sporadic do not oppose any serious obstacle, since there must always be latent hereditary mnemism in the cells and organs ready to manifest itself whenever more recently acquired characters are prevented from being developed in their proper succession. This is the most frequent form in which reversions are found among Ammonitinae.

One of the greatest recommendations of this theory as a working hypothesis, besides its plausible application to the explanation of such difficulties, is that it does not oblige us to begin as in a corpuscular theory by assuming an unprovable constitution of the germ plasm and an equally unprovable, and also in this case, inconceivable mechanism in the body by which specimen samples of these germs are attracted and finally concentrated from all parts into the spermatozoa and ova of every zoon.

It does not oblige the student to assume with Weismann an immortal germ plasm and a mortal somatoplasm in the body, the former alone capable of transmitting characteristics but prevented from acquiring them, the latter capable of acquiring them to any extent but not able to transmit them. This paradox can only be accounted for by supposing organic differentiations between germ plasm and tissue plasm which cannot be demonstrated and are in direct contrast to the statements of the morphic uniformity of young cells in structure, aspect, and origin. Such vast differentiation would be accompanied in Metazoa by some traceable change of structure taking place very early in the embryo when growth force was at its maximum; but there is nothing of this sort. The reproductive cells are not ripe until, like other tissue cells, they have passed through certain stages of development. The immortals behave, in other words, just like mortals while growing up, and in old age they and their carriers, the generative organs, suffer from degeneration as a rule before many of the other tissues give way. In fact the so-called immortals are shorter lived in the individual so far as their functional efficiency is concerned than their mortal brethren.

The mnemonic theory is perfectly consistent and adds strength to Spencer's theory of heredity, which makes no assumption of gemmules or distinct organic peculiarities that cannot be tested by observation. This theory is as follows: "That changes of structure caused by changes of action, must also be transmitted, however obscurely, from one generation to another, appears to be a deduction from first principles—or if not a specific deduction, still, a general implication. For if an organism A, has, by any peculiar habit or condition of life, been modified into the form A′, it follows inevitably, that all the functions of A′, reproductive function included, must be in some degree different from the functions of A. An organism being a combination of rhythmically-acting parts in moving equilibrium, it is impossible to alter the action and structure of any one part, without causing alterations of action and structure in all the rest; just as no member of the Solar System could be modified in motion or mass, without producing re-arrangements throughout the whole Solar System. And if the organism A when changed to A′ must be changed in all its functions; then the offspring of A′ cannot be the same as they

would have been had it retained the form A. It involves a denial of the persistence of force to say that A may be changed into A′, and may yet beget offspring exactly like those it would have begotten had it not been so changed. That the change in the offspring must, other things equal, be in the same direction as the change in the parent, we may dimly see is implied by the fact, that the change propagated throughout the parental system is a change towards a new state of equilibrium—a change tending to bring the actions of all organs, reproductive included, into harmony with these new actions. Or, bringing the question to its ultimate and simplest form, we may say that as, on the one hand, physiological units will, because of their special polarities, build themselves into an organism of a special structure; so, on the other hand, if the structure of this organism is modified by modified function, it will impress some corresponding modification on the structures and polarities of its units. The units and the aggregate must act and re-act on each other."[1]

According to the theory of mnemogenesis, it can be reasonably assumed that "the habit or condition of life" which originates characteristics is attributable to memory and the recurrence of the characteristics in successive forms to the mnemism of the cells acting inevitably and automatically, unless interfered with by other causes, as they come into being through the action of growth force. If this be true, the cells must move in accord as stated by Spencer in the same direction and reproduce the same characters in the same succession as that in which they first arose in accordance with the essential known characteristics of mnemism and genism. This gives a definite meaning to Spencer's otherwise vague statements of what might be called *the drift of polarities towards equilibrium*, and enables an observer to compare the phenomena of mnemonics and genesiology.

These remarks are not introduced here as an adequate statement of this hypothesis, but simply to show that mnemogenesis can claim to be a reasonable explanation, as open to positive proof as any other, and also to demonstrate that the term auxology or bathmology is inappropriate to cover the study of phenomena which can be attributed to forces so different in all their manifestations from those that govern the growth of an organism.

[1]The principles of biology, v. 1, p. 255–256, Amer. ed. 1872.

I have referred above to classes of morphic characteristics that cannot be considered as based upon increments of growth, but there are also others which are important for a clear conception of genesiology and bioplastology. Minot's researches enable one to see clearly that the reduction of parts or characteristics which takes place through the action of the law known as the law of acceleration in development (often also descriptively mentioned as abbreviated or concentrated development) cannot be considered as due to growth.

It seems probable from my own researches published in various communications, but more especially in the "Genesis of the Arietidae,"[1] that the action in this case is *a mechanical replacement of the earlier and less useful ancestral characteristics and even parts by those that have arisen later in the history of the group.* We can fully understand the phenomena of acceleration in development only when we begin by assuming that the characteristics last introduced in the history of any type were more suitable to the new conditions of life on the horizon of occurrence of the species than those which characterized the same stock when living on preceding horizons. These new characters would necessarily, on account of their greater usefulness and superior adaptability, ultimately interfere with the development of the less useful ancestral stages and thus tend to replace them. The necessary corollary of this process would be the acceleration or earlier appearance of the ancestral stages in direct proportion to the number of new characteristics successively introduced into the direct line of modification during the evolution of a group.

If this be true it can hardly be assumed that the loss of characteristics and parts taking place in this way is directly due to growth force. If growth has anything to do with these phenomena it must act indirectly and, as in the repetition of other similarities and parallelisms, under the guidance of heredity.

This law since its first discovery has received verification from a number of sources and is fairly entitled to rank as a fundamental law of genesiology.

The phenomena of development which have been observed as the manifest results of the action of this law have been called by

[1] Smithsonian contributions to knowledge, v. 26, p. 40–48, 1889; also Mem. mus. comp. zool., v. 16, 1889.

various names, not only accelerated development but every possible modification of this; thus we find "concentrated," "abbreviated," "shortened," "omitted," all applied to the same effects. It is, therefore, time that it should receive accurate scientific designation. The term TACHYGENESIS from ταχύς, meaning quick or speedy, is therefore proposed, and the original title "law of acceleration" should become the descriptive, popular term.

Professor Cope has given the fullest explanation of this law but has joined it with retardation. Thus from his point of view, if I rightly understand him, inexact parallelism in development or failure to reproduce any hereditary characteristics is due to a tendency which appears in organisms and works in parallel lines with acceleration. The law being in his conception of a double nature, thus he says on page 142 of his "Origin of the fittest," "The *acceleration* in the assumption of a character, progressing more rapidly than the same in another character, must soon produce, in a type whose stages were once the exact parallel of a permanent lower form, the condition of *inexact parallelism*. As all the more comprehensive groups present this relation to each other, we are compelled to believe that *acceleration* has been the principle of their successive evolution during the long ages of geologic time. Each type has, however, its day of supremacy and perfection of organism, and a retrogression in these respects has succeeded. This has no doubt followed a law the reverse of acceleration, which has been called *retardation*. By the increasing slowness of the growth of the individuals of a genus, and later and later assumption of the characters of the latter, they would be successively lost. To what power shall we ascribe this acceleration, by which the first beginnings of structure have accumulated to themselves through the long geologic ages complication and power, till from the germ that was scarcely born into a sand lance, a human being climbed the complete scale, and stood easily the chief of the whole?" And again on page 182 of the same work: "*Acceleration* signifies addition to the number of those repetitions during the period preceding maturity, as compared with the preceding generation, and *retardation* signifies a reduction of the numbers of such repetitions during the same time." Thus from Cope's point of view tachygenesis is the law of progression, and retardation is the law of retrogression, and they are both essential parts of his law of acceleration and retardation.

Haeckel alludes in general terms to the law of abbreviated development in his "Morphologie der organismen," and in his "Anthropogenie" published in 1874 substantially agrees with Cope in his view of the law and uses the term "palingenesis" for the exact repetition of characteristics which occurs in the earlier and simpler forms of a phylum, and "cenogenesis" for the abbreviated or highly accelerated cases of inexact parallelism of the young of more complex forms with their ancestors.[1]

[1] During the writing of this paper I took from Cope the statement made above although unable to find any verification of it in Haeckel's Anthropogenie (1st and 2d editions both dated 1874), but since the above was in press I obtained a copy of the 4th edition (1891) and the reading of this has caused me to entirely alter my opinion with regard to Haeckel's opinions. He certainly had at that time, 1891, what seems to me erroneous and inadequate views of the nature and action of the laws of tachygenesis and gave it too limited application. He also used the terms palingenesis and cenogenesis differently from the way in which Cope and others have used them in this country.

Haeckel states (Anthropogenie, 4th edition, p. 9, Leipzig, 1891) that "Palingenetische processe oder keimesgeschichtliche wiederholungen nennen wir alle jene erscheinungen in der individuellen entwickelungsgeschichte, welche durch die conservative vererbung getreu von generation zu generation übertragen worden sind und welche demnach einen unmittelbaren rückschluss auf entsprechende vorgänge in der stammesgeschichte der entwickelten vorfahren gestatten. Cenogenetische processe hingegen oder keimesgeschichtliche *störungen* nennen wir alle jene vorgänge in der keimesgeschichte, *welche* nicht auf solche vererbung von uralten stammformen zurückführbar, vielmehr *erst später durch anpassung der keime oder der jugendform* an bestimmte bedingungen der keimesentwickelung hinzugekommen sind. Diese onogenetischen erscheinungen *sind fremde zuthaten* welche *durchaus keinen unmittelbaren schluss auf entsprechende vorgänge in der stammesgeschichte* der ahnenreihe erlauben, vielmehr die erkenntniss der letzteren geradezu fälschen und verdecken."

So far as one can get at Haeckel's opinions from such expressions as the above, it is obvious that he views shortened or abbreviated development in a very distinct light from that to which I am accustomed. He speaks of it as due to the introduction of "fremde zuthaten," as "cenogenie oder störungsgeschichte" and further, to make his meaning clearer, on page 11 he divides cenogenetic phenomena into "Ortsverschiebungen oder heterotopien" and on page 12 "Zeitverschiebungen oder heterochronien." Organs or parts may be developed heterotopically, that is, out of place or in a different part of the body from that in which they originated; or heterochronically, that is, earlier in time during the life of the individual than that in which they originated, and he also speaks of the latter as "ontogenetische acceleration" using exactly the adjective applied in this country many years beforehand but that fact does not seem to have been considered worthy of his attention. Haeckel then proceeds to add: "Das umgekehrte gilt von der verspäteten ausbildung des darmcanals, der leibeshöhle, der geschlechtsorgane. Hier liegt offenbar eine verzögerung oder verspätung, eine *ontogenetische retardation.*" This is probably what Cope alludes to in his quotation of Haeckel and certainly this is a restatement of Cope's law of retardation with, however, the omission of any reference to the original discoverer. It will

Either through want of acquaintance with good examples of retardation or because of a different point of view, I have not been able to see any duplex action in the law of acceleration. To me it is the same law of quicker inheritance which is acting all the time in the phylum at the beginning, middle, and end of its history, as will be seen by the explanations given above. In Insecta[1] I have tried to apply it to the explanation of the peculiar larval forms of

be gathered from the text above, first, that I view acceleration, as a normal mode of action or tendency of heredity acting upon all characters that are genetic, or in other words derived from ancestral sources; secondly, that a ctetic or in other words newly acquired character must become genetic before it becomes subject to the law of tachygenesis. Haeckel has evidently confused ctetic characters like those of the so called ovum of Taenia, the pluteus of echinoderms, and the grub, maggot, and caterpillar of insects, which have caused the young to deviate more or less from the normal line of development as determined by the more generalized development of allied types of the same divisions of the animal kingdom, with all normal characters that are inherited at an early stage in the ontogeny, and considers them all as heterochronic. It is very obvious that they are quite distinct, and while the ctetic characters may have been larval or even possibly embryonic in origin and may not have affected perceptibly the adult stage at any time in the phylogeny of the group, they are, however, subject to the law of acceleration and do affect the earlier stages as has been shown in Hyatt and Arm's book on Insecta. Such characteristics do of course contradict the record if we consider that the record ought have been made by nature according to anthropomorphic standards and in this misleading phraseology they are falsifications of the ontogenetic recapitulation of the phylogeny. In a proper nomenclature, framed with due regard to natural standards such expressions are inadmissible. There is absolutely no evidence that characteristics repeated in the younger stages of successive species and types owe their continuance in likeness to ancestral characters to other than heredity. This likeness may be interfered with or temporarily destroyed by extraordinary changes of habit as among the larvae of some Insecta and the forms alluded to above, or among parasites in different degrees, but the obvious gradations of the effects of these changes show that hereditary tendencies are not easily changed in this way. There are comparatively very few forms having doubtful affinities even among the parasites. It is also evident that the novel larval characters in their turn speedily become hereditary and are incorporated in the phylogeny and recapitulated in the ontogeny.

It may be seen from this that in dividing tachygenesis into palingenesis and cenogenesis the writer has followed Cope rather than Haeckel and there is a serious objection to the use of cenogenesis at all since it is from κενός meaning strange, and was first applied by Haeckel in such a way that both by his statements and the derivation it ought to be confined to types like larvae of the Echinodermata, Insecta, etc., and parasites in which acquired characters do interfere with the ontogenic recapitulation for a certain time. Normal types in which tachygenesis occurs in a marked way might be called tachygenetic. Palingenesis and palingenetic might be confined to generalized forms in which the ontogeny was a more or less prolonged recapitulation of the phylogeny. This would avoid the need of using a new term.

[1] Guides for science teaching, Boston soc. nat. hist., no. 8.

those animals which often present retrogression through suppression of ancestral characters in the young, although their adults are perfectly normal and perhaps progressive. Consequently palingenesis and cenogenesis are, from my point of view, simply different forms of tachygenesis, and there is no boundary or distinction between them. In other words retardation or retrogression occurs because of the direct action of tachygenesis upon more suitable and more recently acquired characteristics which are driven back upon and may directly replace certain of the ancestral characters causing them to disappear from ontogenetic development.[1]

The law of tachygenesis as defined by the writer acts upon all characteristics alike and is manifested in genetically connected phyla by an increasing tendency to concentrate the characteristics of lower, simpler, or earlier occurring, genetically connected forms in the younger stages of the higher, more complicated or more specialized, or later occurring forms of every grade, whether the characteristics arise in adults or in the younger stages of growth. Since my first publication in 1866 the law has become clearer to me, but I have made no fundamental change in the conception. The application of the law to degenerative characteristics appears

1 Specialization by reduction of parts is evidently included under the head of retardation by Cope; thus in "Origin of the fittest." p. 353, he says that "change of structure during growth is accomplished either by addition of parts (acceleration) or by subtraction of parts (retardation)." So far as my experience goes, in the major number of cases the parts or characters that are undergoing reduction disappear according to the law of tachygenesis. They reappear in the ontogeny at earlier and earlier stages or exhibit this tendency in the same way as characters of the progressive class, but their development is not so complete as in ancestral forms. In this sense they can be regarded as retarded or thrown back in their development. There is, however, another way of formulating the expression for this. Instead of regarding this disappearance by retrogressive gradations as due to a tendency opposed to acceleration, is it not a tendency of the same kind? That is to say, do not the parts and characters show a tendency to disappear earlier and earlier and are they not in most cases at the time of disappearance present only in earlier stages of growth than that in which they originated in ancestral forms?

Is not the case of the wisdom teeth exceptional? The frequently extremely late external appearance of these is not accompanied by a later origin of their rudiments in the jaw. Although they may not appear in many cases above the gum until a person is past fifty is not this real retardation due primarily to the fact that they are deficient in growth-power (tending to disappear from disuse, etc.) and secondarily to their internal position. When they cease to be able to break through the gum, will they not still continue to develop at the same stage as the other teeth and will not their rudiments be likely to be present at this early stage long after they have ceased developing into perfect teeth?

to me to explain why there are degenerative forms in the phylum which are indicated by the senile stages of the individual.

The degenerative changes of the senile period may and practically in all cases do tend to the loss of the characteristics of the adult period and consequently in extreme cases bring about not only the loss of a large proportion of progressive characteristics but loss in actual bulk of the body as compared with adults, as has been stated above. This is usually regarded as due to the failure of the digestive organs or defective nutrition, and this may be true in many examples; but on the other hand, it often begins in individuals long before there is any perceptible diminution in size, and may occur in dwarfs and in some degenerate species in the early stages, and finally in series of species according to the law of tachygenesis, so that one is led to believe that the tendency to the earlier inheritance of degenerative modifications producing retrogression is inheritable like the tendency to the earlier inheritance of additional or novel characteristics producing progression. Thus this law applied to progressive or retrogressive groups explains the mode in which their progression or retrogression is accomplished so far as the action of the laws of genesiology are concerned.

I have frequently tried to point out the obviously superfluous and erroneous character of the assumption that heredity should tend to act in two opposing ways at the same time. That it should, while bringing about or directly causing the perpetuation of like characters in endless chains of individuals, simultaneously produce or have a tendency to produce variation in any one of these links, is beyond belief. That it should act like gravity as a centripetal force holding the type true in the phylum and yet at the same time tend like a centrifugal force to make the same structures fly away from the type and put on novel characteristics, is obviously contradictory.

There are, however, other causes for variations, among them the union of the two parents, which Weismann has too strongly accented. That new combinations of characters may be produced in the young by the union of the characteristics, of the parents can hardly be denied even by those who are opposed to Weismann's mode of handling this class of phenomena. But that these combinations are important sources of origin for permanent variations and that they make an impression upon the

organism which is ineradicable and lead to the foundation of hereditary differentials and the arising of new stocks may well be doubted, since there is no adequate proof of this position. In fact it may be said that what little is positively known in this direction is opposed to Weismann's theory.

Thus Hatschek entertains the opinion, founded upon Galton's observation, that the mingling of the sexes practically tends, as do all the manifestations of genetic forces, to hold the organism true to the normal or typical form of the species or breed. Minot in his masterly work "Human embryology," agrees with Hatschek and states that he is inclined to maintain with him that reproduction is apt to correct variations and so preserve the specific type. In fact, one can hardly admit without positive proofs that characteristics derived from purely hereditary sources can be variations in the same sense and having the same influence in founding new forms as those that arise from the action of other and less conservative influences.

Cope and perhaps all of the supporters of dynamical theories of genesiology in this country have opposed these opinions more or less. The entire nature of genism, so far as it is known, tends to hold back an evolving line of characteristics or forms from variation or departure in new directions, and in the old of the individual and in the decline of a type may even force the organism to repeat more or less the purely morphic characters of the younger ancestral forms after the suppression of the variations acquired in the intermediate periods of development and evolution.[1]

Thus the study of the relations of the cycle is directly opposed to Hurst's views that variations preceded heredity and that the latter arose out of the inevitable repetitions of variations. If the nature of genism has been approximately defined above, it is the repetition of similarities which is apt to take place. The repetition of variations depends upon their duration and fixation in the organism for a sufficient time, so that they become incorporated similarities and can be taken up and carried forward into other forms by genism. Genesiology, therefore, to sum up the matter in a few words, deals with the problems of the perpetuation of forms and characters, whether arising through growth by fission or through the conjugation of two organisms.

[1] See remarks upon "Bioplastology" and "The cycle."

CTETOLOGY,[1] OR THE STUDY OF ACQUIRED CHARACTERISTICS.

Weismann and his supporters deny that ctetic or acquired characters are inheritable, but it is safe to make the assertion that this will not be maintained by the students of bioplastology. Within the limits of my own experience in tracing the genetic relations of varieties and species of fossil cephalopods and other groups through geologic time, although I have tried to analyze the behavior of all kinds of characteristics, I have failed to find any such distinctions. If Weismann's theory is true it ought to be practicable to isolate in each type some class or classes of modifications that would be distinguished by the fact that they were not inherited.

It is practicable to isolate inherited characters from new variations which have not become fixed in any phylum. It is also practicable to point out characters which are transient in various ways appearing in individuals but not in varieties, in species but not in genera, and so on. When one has by this system of exclusion arrived at the end of the list he finds that there is no class of characteristics which may be described as non-inheritable. The new variations of any one horizon which can be isolated from inherited ones are not distinguishable in any way from others which occurred previously. Later in time these new variations in their turn become incorporated with the younger stages of descendants. The transient characters of the zoon also do not differ in any way from others that are inherited in allied species, genera, etc. For example, the position of the siphuncle is so variable in some species of Nautiloidea that it is not characteristic of the species, in others of the same order it is invariable within a certain range, and finally in some genera it is invariable. In the Ammonoidea, derived from the same common stock as the Nautiloidea, this organ attains a fixed structure and is invariably ventral from the Devonian to the end of the Cretaceous, although in number of forms and genera the ammonoids far exceed the nautiloids. All characteristics, even those observable in some groups only in old age, are found in the adults of other groups, and finally in the young of the descendants of

[1] **Κτητός**, something acquired or gained.

these, according to the law of tachygenesis. Everything is inherited or is inheritable, so far as can be judged by the behavior of characteristics. Cope has ably sustained this opinion in all his writings and has called it the theory of "diplogenesis" in allusion to the essentially double nature of the characteristics first ctetic and then genic.

It is probable that what has been called effort is the principal internal agent of organic changes as first stated by Lamarck, and subsequently rediscovered and first maintained by Cope and subsequently by others in this country. The modern school of dynamical evolution, or the Neolamarckian school, which has adopted this theory as a working hypothesis, regards effort as an internal energy, capable of responding to external stimuli. They include under this name both the purely mechanical or involuntary, as well as the voluntary reactions of organisms, whether these are simply plasmic, or cellular, or occur in the more highly differentiated form of nervous action.

The word "effort" has mental connections with conscious endeavor, and when we enlarge the definition so as to include purely mechanical organic reactions, this obliges every one to make an effort to rid himself of old habits of associating it with psychic phenomena. It not only imperfectly explains what is meant, but it does not of itself fully convey the idea of a force capable of moulding the parts of the body into new forms, and cannot be used at all for the characteristics which originate through its action.

No apology is therefore needed for the use of Entergogenism for the popular term effort derived from ἐντός, meaning within, and ἔργον, meaning work or energy. This term does not interfere with the name given to the general theory by Professor Cope, kinetogenesis, in allusion to its dynamical character as a theory of genesis, but is supplementary to this more general title. It is also quite distinct from his neurism or nerve force, and phrenism or thought force, although both of these, if we rightly understand him, are certain forms of entergogenism.

The part entergogenic energy or entergogenism has played in the production of normal reactions, hypertrophy, etc., is well known, and the fact that an organism cannot move or respond to external stimuli without its aid, needs no illustration. It seems equally plain that modifications of structure and form follow as the results

of such repeated actions, developing into habits, and that these necessarily end in the permanent establishment or fixing of these modifications in varieties and species.

This theory accounts satisfactorily for the so-called mysterious suitability of organic structures for the work they have to do. Such a force, capable of producing changes of structure and sensitive to the impinging action of external physical conditions, must work in directions determined by these two factors, *i. e.*, the structures already existent in the organism and the external forces themselves. It is obvious that these actions and reactions must produce habits and changes of structure which are direct responses to the environment. To use the Darwinian phraseology, one can say that the variations thus produced are one class of natural selections, and I have called them in other publications *physical selections*, although it is likely that the use of the word selection in any way may convey an erroneous idea of my meaning. Selection implies the choice of some characters or tendencies out of a number of others, and in the minds of most naturalists it also implies the survival of the fittest chosen by the working of the struggle for existence in two directions, in one direction, between contending organisms, and in the other, between the same organisms and their surroundings.

The above was written before I read "Energy as a factor in organic evolution,"[1] in which Dr. John A. Ryder discusses the relations of the statical and dynamical phenomena of development and evolution, using the terms ergogeny and ergogenetic for all the modifications produced by organic energy, and considers kinetogenesis and statogenesis as divisions of the first named. These instructive speculations and observations were written to show that the changes of form produced by motion, and those modifications or conditions which may be properly considered as due to the conditions of equilibrium, are often reached, as is claimed by Ryder, as the result of kinetogenesis and are considered by him as statogenetic. These are interesting in connection with the above, and support the remarks made with reference to the use of terms like "avolution," and are substantially in agreement with the general views taken in this essay, although taking up a side of the mechanics of evolution not discussed here.

[1] Proc. Amer. philos. soc. Philadelphia, v. 31; reprint May 18, 1893.

It is obvious that there is no struggle for existence in the keratose sponges of the Mediterranean as compared with those from Bermuda between these and those of the West Indies, nor yet between the species or zoons of these within these separate localities. The common characters that distinguish all the species of Keratosa in each basin are the direct product of the action of the surroundings, and the entergogenic reactions of the poriferous organism has made it suitable to its surroundings, not because nature has selected some of its structures, but because it was constrained by these factors to grow in certain ways within each of these basins. Their characteristics in this case are probably acquired in an analogous way to those of a drop of rain or of molten lead which becomes round in falling through the atmosphere. If these drops possessed an initial power of resistance and peculiar forms, and were only gradually modified as they fell into drops, the similar forms and the similar drops would be no more due to selection in one case than in the other.

The only known cause of modification as demonstrated by the suitability of variations and existing characteristics, and by the more direct demonstration of experimentation, is of course the physical forces of the surroundings. These certainly have the power to originate modifications, either through their assumed direct action upon the growth of the parts, or through their power to excite entergogenic reactions and modifications in organisms.

It is certainly not a very acute analysis of the facts which attributes to external causes exclusive power in producing modifications in many cases, as is now largely done by experimental zoologists. For example: Brauer and the author have both pointed out this defect in the accepted explanations of the famous Schmankewitsch experiments upon Artemia, and the same may be said of the explanations of all experimenters who do not take into account the reactions of the organisms themselves.

The physical forces of the surroundings must act through the medium of internal movements, and this is shown clearly in the nature of modifications produced which are extra growths or substitutions of characteristics due to changes of functions, etc., or the partial or absolute obliteration of these due to the failure of genetic force to repeat characteristics in the presence of opposing influences and superimposed characteristics as in extreme cases of tachygenesis and cenogenesis.

Ctetology should also, however, include the study of the action of physical forces when they either actually do produce direct effects upon organisms, or may be assumed to act in this way. The action of changes in light, food, heat, and moisture may yet be proven to cause modifications that cannot be included under the head of entergogenic reactions without danger of confusion.

Maupas gives exceedingly instructive examples of this class and quotes other authorities who have investigated their effect in Protozoa.

Beddard gives a number of examples of such modifications in his "Animal coloration," and Semper has also discussed the same subject more extensively in "Die naturlichen existenzbedingungen der thiere."

The use of the term entergogenesis would make it practicable to indicate the essential distinction existing between the modifications produced by internal forces and those arising as the direct results of physical or chemical action by means of the antithetical term ectergogenesis and ectergogenic, and both of these would then be included under Ryder's term ergogenesis.

These explanatory remarks serve to show that this is a branch of research which needs to be isolated from auxology and genesiology since it is devoted to the study of the origin of ctetic characteristics and therefore necessarily considers all of the internal reactions of the organisms in response to the action of physical forces, as well as the more obscure reactions of structures which are produced by (or supposed to be produced by) the direct physical or chemical action of external physical forces alone.

To sum up the objects of ctetology as has been done with growth and genesiology, it may be briefly stated as dealing with all the characters that arise from the union of two factors, the physical stimuli of the environment and the reactions of the organism.

Bioplastology.

The separation of auxology and genesiology and ctetology shows also the study of the correlations of ontogeny and phylogeny to be distinct from any one of these, and this branch of research can

be designated by the term BIOPLASTOLOGY from βιός, life, and πλαστός, meaning moulded or formed.[1]

Biogeny has been used in extra scientific literature by Fiske with the same meaning as bioplastology, and Haeckel has named the law of embryonic and ancestral correlation the law of biogenesis, but there is a strong objection to both of these. *Biogenesis* is the name given to the theory of the origin or genesis of life from life in contradistinction to the assumption of spontaneous generation, or abiogenesis, and has a well established place in scientific literature. Therefore, while the law of correlation of the stages of development and those of the evolution of the phylum may, if one chooses, be called a law of biogenesis, it is more accurate to consider it a law of correlation in bioplastology, or better still *the law of palingenesis*, since it is the law of the regular repetition of ancestral characters; and this exactly expresses what the discoverer (Louis Agassiz) saw and described.

This branch of research is necessarily founded upon the laws of growth and genesiology and ctetology, but it is directly occupied with the study of the morphogenesis of individuals and types, especially their fossil remains, among which evidence can be gathered, not only from the relations of the epembryonic[2] periods of ontogeny and the corresponding periods of phylogeny, but from the actual succession of forms in time.

This evidence among cephalopods, brachiopods, corals, pelecypods, and other animals having hard parts, which are present in all stages of epembryonic life of well preserved fossils, is destined to furnish more complete series of facts in some directions than can be obtained by the study of recent forms alone or by experimentation. The limitations of time cannot be overcome by the observer of existing life, and the study of the natural succession of forms in any genetic line from the beginning to the end of the

[1] Bioplasm, bioplast, bioplastic have already been used by Beale and others for the living cell and its contents but the term bioplastology has not been used nor have the names proposed by Beale been generally adopted. If they were, bioplasmology would cover the requirements of students of such phenomena and there is already in use plasmology with about the same meaning, and histology for the descriptive side of the study of cellular structures.

[2] The prefix para, past or beyond, cannot be used here for fear of confusion with paragerontic, etc., and I have therefore taken ἐπι and embryonic, meaning all stages of development after the embryonic, including the senile.

evolution of the cycle can only be pursued successfully by workers in phylogeny.

Heretofore the transmission of similar characteristics and tendencies has been supposed to be confined necessarily to those that appeared before the expiration of the reproductive period in the individual. This doctrine is not supported by the facts that form the basis of bioplastology, since the repetition of similar characteristics also takes place in the decline of life, and senile characteristics are as clearly parallel in different individuals, species, genera, and so on, as in their young. It must be remembered, also, that this assumption utterly disregards heredity, as exhibited in the propagation of characteristics in organic reproduction by fission of autotemnons.

Characteristics of organs and of parts are, with certain exceptions, based upon increments of bulk during the progressive stages of development, and consequently to a certain extent genetic energy, which controls these or directs them into parallel lines of reproduction, can ideally, at least, be separated from growth force. When the extreme of old age is reached and absolute decrease in bulk takes place, together with the disappearance of characteristics which have been elaborated previously, there is no cessation of the reproduction of similar characteristics. The manifestations of the working of genetic energy, or that energy which holds the type true to its own breed through parallel development, are just as powerful on the verge of natural decease, and even more marked in some respects, than during the adult period. In the young hereditary similarities derived from more or less remote ancestors are repeated, but these are more and more overgrown and replaced by more recently acquired characteristics as the adult period is approached. In old age these more recently acquired characteristics disappear, and in consequence of their disappearance, certain parts of the body and finally the whole body assume aspects which can be more or less closely compared with those of the same parts and of the entire body in the young before the differential characteristics of the adolescent and adult periods arose.

If now one compares different individuals of the same species, it is easily seen that their younger stages of development are identical, and that they diverge as they grow older until the adult

period of full maturity is attained. Then as senility sets in and certain parts are lost or become withered, pronounced similarities again begin to appear. Thus in old age, especially in extreme old age, these same individuals are more closely parallel in aspect and character than during their adult periods.

The same law holds in the evolution of the genus, family, or group, and the result is, as I have tried to point out in several papers, that retrogressive forms occurring in genera, or families, or larger groups of the same type, are apt to have similar forms in their retrograde or terminal members, which occur when the type is approaching extinction. Such genetic series, therefore, usually differ most when they are at the acme of their evolution in time. Thus, like different individuals of the same series, they are more alike just before they cease to exist than at the height of their existence in time.

One can judge of the power of genism only by the more or less exact parallelisms produced. This is the law by which the embryologist proceeds when he successfully uses the stages of development in a young animal to indicate from what ancestors it came and in what group he must place it, and it is this law to which the breeder appeals when he points out the markings which always occur in the pure-blooded specimens of any special stock. Consequently, if parallelisms are more exact in old age than in adults, these results must be attributed to the only cause that is known to produce such effects, and this is genetic force.

I am not discussing here what causes senile decline and degeneration in the parts of an individual and the consequent loss of characteristics, but I am trying to reply to the questions why, when this loss takes place, the oldest stages of different individuals of a species and the corresponding phylogerontic types of different groups, arising from the same common ancestor, resemble each other. It seems to me to be in large part, at any rate, attributable to genism, which holds the development of the individual and the evolution of the phylum true to the type even when growth is losing the power to continue the existence of individuals.

Thus the evolution of forms in a phylum, or phylogeny, presents similar parallelisms to those observed in the development of the individual, or ontogeny. This shows still more clearly that heredity is distinct from growth since the individual and the type

remain true to the stock in their strictly morphic lines of modification as long as they do not become parasitic, that is, as long as they remain subject to the similar surroundings of the external world. In this paper the exceptions due to parasitism and all other facts than those bearing on the suitability of the term to be employed to designate the researches which deal with the correlations of ontogeny and phylogeny, are left out of consideration.

Heredity is obviously manifested entirely in the results of growth and appears chiefly in the cytoplasmic structures which Dr. Minot so clearly places before us as constantly increasing with age while the comparative size of the nucleus, which represents the power of growth force, decreases. Whether this be granted or not, it can hardly be denied that, in describing the development of organisms along phylogenetic lines, we are dealing with cycles of progression and retrogression which are quite distinct from the growth of the body as determined by the law that governs its increase or reduction in bulk, and that one cannot describe the study of both series of phenomena under the same general term without danger of confusion.

I have several times used the term morphogenesis in a more descriptive sense than that in which it has been used by Haeckel. This philosophic thinker and naturalist divides morphology into anatomy and morphogeny, and uses morphogeny in nearly the same sense as the proposed term bioplastology, including under it ontogeny (or embryology) and phylogeny (or paleontology). Subsequent parts of his text show that he really means by ontogeny[1] the entire life of the individual and all its transformations, and by phylogeny the entire history of the evolution of the phylum. The use of paleontology as a co-extensive with phylogeny is obviously wrong, since phylogeny, meaning thereby the evolution of the phylum, is perhaps better studied by means of fossil remains, but it reaches into recent times, and should include living animals as well as all of their fossil remains. This somewhat obscures this great discoverer's meaning, but there can be no doubt that he used both ontogeny and phylogeny in their widest application and understood the phenomena in their more general and physiological correlations.

[1] The researches of Maupas do not contradict this statement since his successive generations of Infusoriae, although completing a cycle, are plainly (as pointed out by himself) ontogenic when compared with the ontogenic cycles of the Metazoa.

There is, I think, a decided advantage in substituting bioplastology for morphogeny. This is essentially the genesis of form and is a very convenient term of general application, whereas the study of the relations of the individual and of the phylum necessarily includes the study of the dynamical phenomena of ontogeny and phylogeny. It would be practicable to study morphogeny as ordinarily understood without considering any of the correlations of ontogeny and phylogeny, but it would not be practicable to study bioplastology in this way. The latter is in other words a department of biology which consists of researches upon the correlations of development and evolution by means of both the dynamical and statical phenomena of morphogenesis.

To sum up in a few words the rather ambitious aims of this comparatively new recruit in the army of investigation, it aspires to show that the phenomena of individual life are parallel with those of its own phylum and that both follow the same law of morphogenesis, that, not only can one indicate the past history of groups from the study of the young, and obviously the present or existing progression or retrogression of the type by means of the adult characters of any one organism, but that it is also possible to prophesy what is to happen in the future history of the type, from the study of the corresponding paraplastic phenomena in the development of the individual. Or to put the whole statement into a few words, bioplastology deals with the morphic and physiologic relations of organic cycles.

While growth is the result of one form of organic force, genism, the result of another form of the same force, and etetism, or the acquisition of new characters, still a third form of the same force, the bioplastic relations of organisms are due to the action of all three of these forms of energy in so far as they are concerned in the building up of cycles both in ontogeny and phylogeny.

Whether these claims are well founded or not the nomenclature to be employed is a matter of importance, and should be accurate, appropriate, and convenient for those who are interested in this work, and this paper has been in large part written as a contribution towards this object.

Ontogeny.

Messrs. Buckman and Bather have proposed to substitute a set of improved terms for those previously used by myself[1]; they give the following table :—

Ontogeny, Table (I).

Hyatt 1888.	*Buckman and Bather 1892.*	
(1) Embryologic	(1) Embryonic	(1) Embryonic
(2) Naepionic	(2) Brephic	(2) Infantile or larval
(3) Nealogic	(3) Neanic	(3) Adolescent
(4) Ephebolic	(4) Ephebic	(4) Adult or mature
(5) Geratologic	(5) Gerontic	(5) Senile
(*a*) Clinologic	(*a*) Catabatic	(*a*) Declining
(*b*) Nostologic	(*b*) Hypostrophic	(*b*) Atavic

It would be a waste of time, even if I felt so disposed, to attempt to defend the nomenclature of the first column in this table. The use of terminations derived from λόγος in this way is not defensible and was due to the careless habits of the earlier history of terms still extant in the use of "morphological" instead of "morphic" and in the obligatory use of "physiological" and "geological," etc. The nomenclature of 1888 is inadequate not only on account of etymological faults, which do not, however, trouble me so much as they do those who regard linguistic purity with higher respect, but because it is insufficient and unsymmetrical.

This last object applies with equal force to some of the terms proposed by Buckman and Bather. These gentlemen were hampered by the desire to perpetuate the older terms now in use in this country and for which I am alone unluckily responsible. This also is my own condition, and although I would willingly now suggest an entirely new method, I find after having framed and tested a new one, that it is better not to interfere any farther than is absolutely necessary with the nomenclature of 1888.

[1] See Values in classification of the stages of growth and decline, with propositions for a new nomenclature, Amer. nat., v. 22, p. 872–881, 1888, and Genesis of the Arietidae, Smithsonian contributions to knowledge, v. 26, 1889; also, Mem. mus. comp. zool., v. 16, 1889.

Table II, printed below, is therefore made up of terms which are substantially the same as those suggested by Buckman and Bather, and in it I have also followed a suggestion kindly sent me by letter from Mr. Buckman, in adopting the prefixes "ana," "meta," or "para" for the designation of the substages of development. This has the great advantage of adding to the means of expressing observations accurately, quite as well as by the use of an entirely distinct word, and at the same time preserves in each term a direct reference to the stage to which it belongs. Thus one can speak of the metanepionic or ananeanic substage without referring to the stages in which they occur, and yet the reader will at once recognize to what stages they should be referred.

ONTOGENY, TABLE (II).

Conditions.	*Stages.*	*Stages.*	*Substages.*	*Substages.*
Anaplasis.	Embryonic.	1 Embryonic.	Several.[1]	No popular names
	Larval or Young.	2 Nepionic.	Ananepionic. Metanepionic. Paranepionic.	
	Immature or Adolescent.	3 Neanic.	Ananeanic. Metaneanic. Paraneanic.	
Metaplasis.	Mature or Adult.	4 Ephebic.	Anephebic. Metephebic. Parephebic.	
Paraplasis.	Senile or Old.	5 Gerontic.	Anagerontic. Metagerontic. Paragerontic.	

Recent researches have in my opinion clearly demonstrated that all the stages of development from 2–4 inclusive like the embryonic (1) and the senile (5) will have to be subdivided in studying many groups. These subdivisions are also relatively important and their differences are often well defined.

The ovum and the extreme degraded substage of the senile period represent the widest departures structurally and physiologically from the adult, one being at the commencement and the

[1] These stages were enumerated and more or less described under the names of Protembryo, Mesembryo, Metembryo, Neoembryo, Typembryo in my paper on Values in classification, etc., and to these Jackson added Phylembryo in his Phylogeny of the Pelecypoda, p. 289.

other the termination of ontogenesis. Departing from the ephebic period in either direction towards these extremes one finds the same law. *Contiguous stages of development, when considered in sequence, differ less from each other and from the adult the nearer they are to the ephebic period, and they differ on the other hand more from the adult and from each other in structure and form the nearer they are to the two extremes of the ontogeny.* This is an evident corollary from the phenomena of the ontogenetic cycle and need not be dwelt upon here. It is cited only to show that the differences between the nepionic, neanic, and ephebic stages are less noticeable than those of the embryonic and nepionic or the ephebic and gerontic, and this explains why I did not subdivide the intermediate stages in 1888 as I then did the embryonic and the senile.

I now propose the following nomenclature which does, it is hoped, fuller justice to every stage.[1]

The terminology of the different branches of research which come properly under the head of bioplastology is recognized at present only in the case of embryology, but it is obvious to the student of epembryonic development that similar terms for the study of other stages and periods will in course of time be needed, and in fact the old terms, nealogy, ephebology, and geratology, are cited in that sense in the Century dictionary, and may introduce some confusion. It is not now necessary to discuss this question but only to draw attention to the facts. I therefore pass on to the consideration of the term epembryonic.

Among fossil nautiloids it is rarely practicable, on account of the frequent destruction of the protoconch, to find an embryonic stage. My last work on Carboniferous cephalopods contains descriptions of the entire ontogeny of a number of species with the exception of the embryonic stages. In such cases the fact that the embryology is wholly omitted can be pointed out by the

[1] It is my grateful duty to add that I have had the unremitting help of Dr. C. E. Beecher, and have consulted with Dr. R. T. Jackson of Cambridge, and Mr. J. M. Clarke of Albany, and also with Mr. Buckman, and I wish to express to these gentlemen my indebtedness for suggestions and advice of essential importance. Except in the retention of one term, "nepionic," the nomenclature is more theirs than mine. I also desire to thank Professor Reynolds of New Haven and Prof. William W. Goodwin of Cambridge for the earnest help they contributed to the formation of a table which, for reasons given above, was not used, as well as for advice which influenced the framing of the one finally adopted.

use of the term "epembryonic stages," and this has already been found useful above. It only remains to add that the same prefix is also useful in designating the exclusion of other stages, thus one can speak also of the "epinepionic" or "epineanic" stages in this same way without danger of confusion with any other term.[1]

It is often possible to employ a more specific and characteristic designation than epembryonic. Thus, among shell-bearing forms one can distinguish between the embryonic shell and the true shell; for example, the protegulum and the tegulum of Brachiopoda as defined by Beecher, the prodissoconch and the dissoconch of Pelecypoda as defined by Jackson, the periconch and conch of Scaphopoda, the protoconch and conch of Cephalopoda. In all of these forms it is practicable to speak of tegular, dissoconchial, or conchial stages or periods, meaning thereby all of the epembryonic stages of these types.

Haeckel in his "Morphologie der organismen" sketched the physiology of ontogeny and phylogeny and gave the general correlations of the two series of phenomena, together with an appropriate nomenclature which has been here adopted with some necessary changes.

The dynamical relations of three great phases of evolution in the phylum were designated by Haeckel[2] as the *epacme*, including the rise of the type from its origin, the *acme*, meaning the period of its greatest expansion in members and forms, and the *paracme*, or decline towards extinction, and these phenomena were correlated with the similar physiological phenomena of the ontogeny, and these appear in the table of phyletic terms given below.

Previous to this in the same volume, page 76, Haeckel gives his classification of the development of the individual under three headings: "Anaplasis oder aufbildung (evolutio)," meaning thereby to include the physiological phenomena of all of the stages developed in the four earlier stages of the individual. This is certainly a useful term for the entire series of transformations from the fertilization of the ovum until the progressive stages are all passed through. It does not express nor can it be used for

[1] Post-embryonic is in use for the young stages among embryologists, and is equivalent to the term nepionic, but it is not consistent with the other terms of bioplastology. and is a hybrid.

[2] Morphologie der organismen, v. 2, p. 320–366.

cases of retrogression in which degenerative characters are introduced at such an early age that progression is limited to the embryonic, or to that stage and a part or the whole of the nepionic stage. There are also some examples among parasites in which progression seems to have been reduced so much that one can say it is practically eliminated from all stages succeeding some of the earliest embryonic. For such forms as these the proper term would be PARAPLASIS from παρα πλάσσω, meaning to change the form for the worse, to deform. Thus the stages of such forms could be collectively spoken of as paraplastic with relation to the ontogeny of others of their own type or allied types, whereas they could not be described as anaplastic.

The explanatory word "evolutio" is here used by Haeckel in a confined and erroneous sense. Evolution really means continuity in time invariably accompanied by change, but whether the modification be progressive or retrogressive, or a combination of progression and retrogression, is immaterial. It is obviously better not to use these terms for ontogenic phenomena. There are sufficient terms in "development," "diffentiation of characteristics," "rise," and one has always a slight mental reservation in employing this word for the growth and development of an individual or isolated zoon.

"Metaplasis oder umbildung (transvolutio)" is used by the same eminent authority for the adult period in a general sense, and it appears to the writer to have useful function as a descriptive term especially, since it is uniform with anaplasis and paraplasis. Thus one can describe the metaplastic phenomena or characteristics of the ephebic stage in any form as metaplasis, and also speak of the general meaning of metaplasis without referring to that stage of ontogeny in any special form. The use of "transvolutio" is obviously objectionable, since it introduces confusion and conflicts with the proper definition of "evolutio" or evolution as given above.

"Cataplasis oder rückbildung (involutio)," used by Haeckel for the senile stage, is open to the objection that there is no corresponding Greek word, and also that καταπλάσσω, the only Greek verb to which this term can be referred, means to spread over or plaster. Paraplasis, derived from παρα πλάσσω, meaning to change the form for the worse or deform, is an obviously preferable designation. Thus the paraplasis or paraplastic phenomena of all

the periods of development or only of the paragerontic substage in ontogeny may be spoken of and correctly described under this term.

The use of "involutio" as a descriptive term is objectionable, not only on the grounds given above, but because "involution" and "volution" are both in common use as descriptive terms for the peculiarities of the whorls of Gasteropoda and Cephalopoda. Any modification of evolution is objectionable because it is misleading. For example the word "avolution," supposed to mean things that do not evolve or have not been evolved, represents an unnatural condition. One can of course conceive of matter in a state of more or less stable equilibrium, but there are other words than "avolution" in habitual use to express this conception. It is also to be regretted that it has been applied by several eminent writers to ontogeny, and is probably fairly established in this application. The growth and development of the tissues is in a general way evolution, as much so as that of a colony of Protozoa. But it is also obvious that the product of the development by division of a single autotemnon, which forms a cycle, or when held together so as to form a colony, and the product of the division of an ovum in Metazoa held together more compactly so as to build up an individual or zoon, are not the same as the product of the evolution of an ancestor into a phylum through successive independent forms or ontogenic cycles. One cannot accurately speak of the "growth" of a phylum, nor ought the word "development" to be used for the phylum. Development should be restricted to the zoon or individual or its morphic equivalent among Protozoa, since it expresses more clearly the differences that exist between ontogeny and phylogeny than their similarities, and for the same reason it is advantageous to use evolution for the phylum alone in the sense in which it is commonly employed. The necessity of subdividing the embryonic stage is admitted, and in all probability this really includes several stages with their own substages, but the discussion of this problem must be left to the future. The former subdivision of the gerontic period into two parts also seems to have met with general acceptance, but the terms remain to be settled. Buckman and Bather have proposed *catabatic* to replace my old term "clinologic" taken from κλίνω and λόγος, which is an improvement, but their term "hypostrophic," proposed from ὑποστροφή meaning

a turning round and back, is not equally good. While this is better than the term formerly employed, nostologic, it is longer and not preferable to Nostic, from νοστός,[1] signifying a return in the sense of a journey back to one's home.

This paragerontic stage is in no sense "atavistic" or "reversionary," as it is defined by Buckman and Bather. Reversions are the returns or recurrence of ancestral characteristics in genetically connected organisms which have been for a time latent in intermediate forms. I do not think that we can include in this category purely morphic characteristics which habitually recur in the same individual as the result of paraplasis, or which recur in the paracme of a type more or less invariably. In the individual the resemblance of the smooth round shell of the whorl of the paragerontic ammonoid after it has lost the progressive characteristic of the ephebic stage cannot be considered as a reversion. It is simply analogy of form not structural similarity of characteristics. A better known and more easily understood case is the resemblance of the lower jaw of the infant before it has acquired teeth and that of the extremely old human subject in which these parts have been lost and the alveoli and upper parts of the bony mandible have disappeared through resorption. The forms are alike, but no one would venture to consider the infant's cartilaginous jaw and that of the old man as similar in structure.

The best example of similar phenomena in the phylum known to me is the close resemblance of form between the straight Baculites of the Cretaceous or Jura and Orthoceras of the Paleozoic. These two are often confounded by those ignorant of the essential differences existing in their structure. One is a Mesozoic straight form derived by degenerative processes of evolution from the highly ornamented progressive Ammonitinae of the Mesozoic,

1 Neither of these words has any authority for the termination "ic," but unless one can make some such "corruptions," it is often impracticable to manufacture a consistent set of terms according to the method here adopted. It is obvious that scientific convenience occasionally requires such heroic methods, and this seems a case in which it is justifiable. If the new set of terms here proposed is adopted, there will be no need of employing either "catabatic" or "nostic." These will then be superseded by "anagerontic" and "paragerontic" or by all three terms used for the substages in the table, if the characteristics justify their application. It was necessary, however, to discuss these terms because two distinct sets of names have been used for the subdivisions of the senile period.

and the other is a near relative of the primitive ancestral forms of the nautiloids in the Paleozoic. One occurs in the paracme and the other in the early epacme of the group of chambered shells. They are widely distinct in their structural characteristics, and these differences are greater in the young than at any subsequent stage of their ontogeny. Baculites has a close-coiled shell in the nepionic stage, as has been lately demonstrated by Dr. Amos P. Brown[1] of Philadelphia, and Orthoceras is straight from the earliest stage. The return of a similar form in Baculites in the epinepionic periods of development in obedience to the law of the cycle does not carry the structure back with it to a repetition of the orthoceran siphuncle and sutures.

The structure of an individual during its development might be represented graphically by an irregular spiral of one incomplete revolution which describes a curve, continually increasing its distance from the point of departure until the meridian of the ephebic stage is reached, and then beginning to return. Such a curve would always as a spiral rise more or less vertically, and consequently even if it completed the revolution, must terminate in space. It might, perhaps, reach nearly to the same imaginary vertical plane, but never to any point approximate to that of its departure. Structure separates the extremes of life as widely as possible and does not permit us to regard them as approximate, nor can one regard old age, however complete its return in external form, as a reversion. One of the most noteworthy contributions of bioplastology is that it gives proper values to this class of analogies and shows them to be constantly recurring in the individual and in the phylum in obedience to well ascertained laws of morphogenesis.

Further discussion of this point so far as the terms are concerned is not necessary, since it is now proposed to abandon the older names and adopt "gerontic," as proposed by Buckman and Bather, and also to designate the substages by the same word with an appropriate prefix, ana, meta, or para.

The different stages have been described by Dr. Beecher among Brachiopoda, Dr. Jackson among Pelecypoda, and the author among Cephalopoda; and Buckman and Bather, and also Blake[2] in

[1] Proc. acad. nat. sci., Phila., 1891, p. 159-160.

[2] Evolution and classification of Cephalopoda, Proc. geol. assoc. Lond., v. 12, p. 276-295, 1892.

England, and Würtenberger in Germany, have admitted their existence, and the last redescribed them. Würtenberger[1] has admirably described the phenomena of bioplastology as they occur among Ammonitinae, and correctly interpreted the law of tachygenesis and its action in these forms, but failed to quote either Professor Cope or the author. This omission was not so remarkable as the fact that Neumayr and some other investigators, after they had received the printed records of the work done in the same direction in this country, continued to quote Würtenberger as the sole discoverer of these phenomena and of the law of tachygenesis. Würtenberger's work was apparently independent, and it has higher value on that account, but it needs rectification from an historical point of view.

My own researches have led me to the conviction that still finer classification and minuter subdivision of the developmental phenomena of the nepionic, neanic, and ephebic stages are necessary, and for obvious reasons I shall take my illustrations wholly from the Cephalopoda.

The nomenclature of the youngest of the epembryonic stages, or nepionic, is, naturally, the first to be considered. The term used by Buckman and Bather, "brephic," derived from βρεφίκος, would have been an appropriate substitute for nepionic,[2] but unluckily it was not used in 1888. The latter has been used by authors on this side of the Atlantic in several essays, and is found in the Century dictionary and therefore consistently with the principle adopted by Buckman and Bather and myself, to depart from established terms as little as practicable, it should be perpetuated. It has not deserved the sharp criticism of these authorities, since it is not an "impossible corruption of the Greek." It is a convenient term, and not worse etymologically than one that those authors themselves supported, and another which they proposed. Embryonic has a precisely parallel history, there being in Greek no authority for the use of the termination "ic," and this is adopted by them without comment. Hypostrophic, derived from ὑποστροφή, which also has no authority for its termination in "ic," was one of the terms proposed by them. So

1 Studien über die stammesgeschichte der ammoniten. Ein geologischer beweis für die Darwin'sche theorie. Leipzig, 1880.

2 Originally taken from νήπιος but there is a form νήπιον.

far as the purity of the language is concerned, I see no reason why they should not do this, since there is no Greek word to which "hypostrophic" could be referred that would make confusion. When no confusion can arise from such a source, why should not one be at liberty to add an appropriate euphonic termination in latinizing a Greek word, if it is otherwise suitable?

While desirous of observing all reasonable regulations, such iron-bound shackles upon the framing of nomenclature are not beneficial and should be met by sturdy opposition. They involve a question of principle which is worthy of serious consideration. While it may be conceded that terms which are inappropriate in composition, like nealogic, etc., should be changed, this does not justify the substitution of entirely new names for these, nor upon the same principles ought a word having a termination unjustified by ordinary rules of etymology to be supplanted by another entirely new term. The logical outcome of this practice would be the substitution of some other word for "embryonic," a change delightful to the linguist, no doubt, but confusing to the student. It seems to me, therefore, that there is no valid reason for the abandonment of nepionic, and it is consequently used in this paper to designate the first part of the true conch as distinguished from the protoconch or last of the embryonic stages.

Those who do not believe that there was a protoconch in nautiloids will have to reconstruct this part of the nomenclature in accordance with their own views. Having been reproached by Professor Blake in his address before the Geologists' association in 1892 in London, for holding to this opinion, it is necessary for me to add that there is much new evidence with regard to the existence of the protoconchs and of the cicatrix in nautiloids, and I maintain my former views, because facts in its favor are steadily accumulating.

Granting, therefore, that the conch begins with the nepionic stage, I propose to call the first substage of this period the ananepionic substage. This substage is very similar throughout all the nautiloids on account of the existence of the cicatrix on the point of the apex of the conch and the surrounding comparatively smooth area which is generally elliptical, the apex being in most forms of Nautiloidea cup-like and in section a laterally compressed ellipse, the vertical or ventro-dorsal diameter being the longest.

This stage is well shown in figures of several species, in the Genesis of the Arietidae, p. 10, 11, and in Nautilus pompilius, in Fossil cephalopods of the Museum of comparative zoology — Embryology, v. 3, pl. 3, f. 1, and in a number of figures of Barrande in his "Système Silurien," pl. 487–488, several of which were drawn and given to Barrande by the author. I have described this first substage among the nautiloids under the descriptive name of the "asiphonula," which I now propose to change into PROTOSIPHONULA. Among ammonoids this substage has been forced back into the embryonic stage and has practically disappeared from the conch, probably through the action of tachygenesis. The tendency of the embryo to build a solid calcareous protoconch of imbricated structure may be attributed to the earlier inheritance of the characteristics of the calcareous, apical, aseptate conch of its nautiloid ancestor.

This explanation has been supposed by Professor Blake to show that the protoconch of ammonoids was necessarily identical with the apex of the shell or early part of the ananepionic substage, protosiphonula, of nautiloids. It would have such a meaning, perhaps, if there were a cicatrix on the protoconch of ammonoids and if there were not more or less rugose lumps, supposed to be the remnants of protoconchs, covering up the cicatrices of the apices of the conch in some nautiloids. These facts must be reinvestigated and it must be proved that the latter are not the remnants of shrivelled, horny protoconchs, and that the cicatrix was not a passage way from the embryo into the shell or at any rate an aperture through which the protosiphonula communicated with the protoconch, before one can consider them in a different light or admit any hypothetical explanation.

It will be seen below that I have altered my view in so far as the primary origin and nature of the coecum is concerned. Barrande imagined that my view necessarily implied the passage of the embryo bodily out of the protoconch into the conch, but this was a mistake arising probably from my inadequate statements. The young, when it had passed by growth out of the protoconch or when the anterior parts that had grown out of the protoconch into this position, began to build the shell, and finally at the end of the protosiphonula stage rested in the apex, which was then the first living chamber. The structure of the apex in Endoceras, Piloceras, and Actinoceras, indicates large and direct, open,

tubular connection between the protoconch and the animal when in this first chamber through which the endosiphuncle in the generalized nautiloids, Endosiphonoidea, opened into the protoconch.

The tubular opening of the apex in Endoceras, Piloceras, and Actinoceras, and other genera having a marked endosiphuncle, is not closed by the coecum of the siphuncle as was formerly supposed. It is on the contrary directly continuous with the endosiphuncle, as was first pointed out by Foord in his "Catalogue of British Cephalopoda." This is an attenuated, central, more or less irregular tube formed by the extension of the successive endocones or sheaths. It is more or less interrupted by pseudosepta, and is a separate and distinct organ occupying the axis of the large siphuncle. This organ is continuous with some corresponding part, possibly the mantle of the embryo, which existed in the protoconch. On the other hand, the true siphuncle, including the coecum of the first air chamber, is a secondary organ formed by the funnels of the septa.

The next substage is indicated by the presence of the coecum lying within the apex, and this is formed by the funnel of the first septum and in association with the first septum is universal among Cephalopoda, with the exception of some sepioids, so far as the internal structures are concerned. It has been descriptively named the coecosiphonula. This may be considered as a part of the metanepionic in nautiloids, but among ammonoids and belemnoids it is forced back according to the law of tachygenesis into the ananepionic substage, the calcareous apex of the ancestral shell being consolidated with and disappearing in the calcareous protoconch of these two orders.

The limits of the living chamber which rested upon this first septum have not been determined, but in a general way it may be said that some of the external characteristics of this age are also characteristic of most of the Nautiloidea. The shell is cyrtoceran or curved, the septa succeeding the first septum, that may in different forms be said to belong to this stage, are entire, never have annular lobes on the dorsum, and always have saddles on the venter and dorsum, or are straight. The markings of the external surface are, however, variable and in respect to the latter and to the outline of a section of the whorl at this time the characteristics cannot be considered as of ordinal value.

Although the stages that succeed the nepionic vary externally in different genetic series or phyla and in different forms of the same phylum, so that they cannot be considered characteristic of the entire order of nautiloids, they are very significant when studied in more limited groups according to the comparative method of research employed in bioplastology. I have recently had occasion to use these terms in researches on Carboniferous cephalopods now publishing by the Geological survey of Texas, and those who care to follow this subject farther will find examples of the mode in which I have employed them in the next annual report of the geological survey of that state. It is only essential to say here that each term had its utility tested and was found essential to the accuracy of the descriptions of the stages of development before it was adopted.

I have thus ascertained that among nautiloids of the Carboniferous the metanepionic whorl usually became a depressed ellipse, that is, one with the transverse axis longer than the dorso-ventral, and ornamented with coarse longitudinal ridges, whether the shell was subsequently smooth or remained ridged. The septa succeeding the first septum among nautiloids and attributable to the metanepionic stage have a large siphuncle compared with the ventro-dorsal axis, and this has been called the "macrosiphonula."

The macrosiphonula brings before the observer certain internal characteristics; which, although much altered, appear to have been derived from the earliest known ancestors of the nautiloids, the Endoceratidae. The metanepionic stage is therefore in part in all forms very primitive in spite of the fact that in highly accelerated nautilian shells it is very much modified and also that most of its characteristics are derived from the more recent ancestors of its own ordinal or sub-ordinal, or family or even generic phylum, as is the case in belemnoids and ammonoids and among nautiloids.

The paranepionic substage so far as I know does not carry any characteristics derived from a very remote ancestry but usually in nautilian shells points very definitely to some known or unknown cyrtoceran or gyroceran ancestor. This is broadly shown in the fact that in all of the more generalized forms of nautilian shells the three parts of the nepionic stage occur before the whorls touch. The external characteristics and form of the metanepionic and the whole of the paranepionic substage thus

seem to have been largely derived from the immediate ancestors of the species. They often have their corresponding phyletic forms within their own family or genus, whereas the characteristics of the ananepionic substage are derived from remote ancestors.

Thus by the aid of direct observation it is not difficult to see, *that the substages of development in ontogeny are the bearers of distal ancestral characters in inverse proportion and of proximal ancestral characters in direct proportion to their removal in time and position from the protoconch or last embryonic substage.* It is already generally admitted that this law is true of the embryonic stages themselves with reference to the protembryo, although most observers would hardly dare state this in the same positive terms as here employed because they are confused by what they call abbreviated development. They have not traced the systematic regularity with which the law of tachygenesis works in producing the replacement of hereditary characters in every series of forms, and do not trust or know how to use this law.

That this law of development is also paralleled in the evolution of the phylum, so that *the stages of evolution exhibit the distal ancestral characteristics in inverse proportion to their removal in time and in adult structure from their point of origin*, is a law I have tried to demonstrate in several publications and have only to add that recently gathered evidence is making this position still stronger.

The transformations that distinguish the subdivisions of the neanic stage are very well marked in some forms and less distinctly in others, but I have continually found the need of defining two stages. Ananeanic is a suitable term for the first substage, which is usually well marked in nautilian[1] shells by the first appearance of the impressed zone. This is the name I have given to the area on the dorsum affected by the contact of the dorsum of the growing whorl with the venter of the already formed whorl of the next inner volution. This is either flat, gibbous, or indented in accordance with the form of the venter of the whorl it touches or envelopes, but it is usually indented more or less deeply.

[1] In my Genera of fossil cephalopods nautilian forms have been defined as those having the whorls in such close contact that the dorsum of the enveloping or later formed whorl is modified, either flattened or bent inwardly along the area of contact, and has what is called an "impressed zone."

There is a notable exception. to this rule when in highly tachygenic shells the zone of impression is inherited and the dorsum becomes furrowed before the whorls touch. This is one of the most complete demonstrations of the probable inheritance of acquired characters that I know, and an excellent illustration of the law of tachygenesis. It occurs in some groups of nautilian shells of the Carboniferous and also in the Jura and Cretaceous in some forms and in Nautilus pompilius to a somewhat less degree. In tracing out the distinct phyla to which these different forms belong it can be shown that the impressed zone is invariably consequent upon close coiling, never appearing in ancestral forms in the nepionic period but always later, usually in the ananeanic substage of these more generalized and less closely coiled shells. Then rising in the series to the more specialized nautilian and deeply involved shells this purely acquired character becomes through the action of tachygenesis forced back into the nepionic stage before the whorls touch. It is therefore in these forms entirely independent of the mechanical cause, the pressure of one whorl upon another, which first originated it. One needs only to add that this configuration of the dorsum is never found in adults of any ancient and normally uncoiled shells so far as I know, nor so far as they have been figured.[1]

The ananeanic substage among Carboniferous cephalopods is not only marked by the beginning of the impressed zone but also as a rule by the introduction of correlative changes in the form of the whorl. Thus the hexagonal whorl with an outline similar to that of an inverted trapezoid in section and consequently an obvious repetition of the ephebic whorl of Temnocheilus, and with sutures also like those of the adults of that genus, appears at this stage in Carboniferous cephalopods of several different genera, showing their immediate descent from Devonian Temnocheili.

The first appearance of the annular lobe in the dorsal sutures is correlated with closer coiling and is apt to make its first appearance in primitive nautilian shells at this stage in the impressed zone. This annular lobe occurs also before the whorls touch in Nautilus pompilius, but whether it is strictly correlative with the impressed zone in obeying the law of tachygenesis in Carboniferous forms has not yet been ascertained.

[1] "Phylogeny of an acquired characteristic" Amer. nat., 1893.

In the paraneanic substage transition to the ephebic stage takes place, and characteristics derived from the adults of the immediate ancestors in the same genetic phylum, such as the trapezoidal whorl just mentioned, are replaced by characteristics peculiar to the genus or species. While there are marked distinctions between this and the ananeanic substage, the differences are much less obvious between this and the ephebic stage except in those shells in which this period has degenerate characteristics. In these latter, marked distinctions are likely to make their appearance owing to the disappearance of external ornaments and markings which have been present until near the end of the neanic stage.

The ephebic stage has not been so fully studied among the nautiloids or ammonoids and therefore in both of these orders it may be considered questionable whether any subdivisions are essential. This stage is much prolonged in some forms of Ammonitinae especially those with numerous whorls like the shells of Caloceras, Vermiceras, and the like, and it is quite probable that when its characteristics have received more attention subdivisions will be found to be convenient.

The gerontic stage has been so often described that it is not essential to go over the ground here, and the proposed suppression of the terms catabatic and nostic, etc., has been discussed above, as well as the general meaning of the substages.

Buckman and Bather propose to use the prefix "phyl" for forms occurring in the phylum which represent in their adult characters stages in the evolution of the phylum corresponding with those in the development of the ontogeny, and give an instructive table in which Haeckel's physiologic terms are placed side by side with those proposed for the morphic phenomena. In following out the same ideas the following table has been constructed, which differs from theirs in the use of nepionic, as stated above, and also in the use of phylanaplasis, phylometaplasis, and phyloparaplasis as correspondents of the similar ontogenic terms.

SUMMARY, TABLE III.

Ontogeny.		*Phylogeny.*		
Anaplasis	Embryonic. Nepionic. Neanic.	Phylanaplasis	Phylembryonic. Phylonepionic. Phyloneanic.	Epacme.
Metaplasis	Ephebic.	Phylometaplasis	Phylephebic.	Acme.
Paraplasis	Gerontic.	Phyloparaplasis	Phylogerontic.	Paracme.

Buckman and Bather gave the following appropriate example from Beecher's and my own researches.

"Thus we would say that the Productidae attained their paracme in the Permian, when they were represented by the phylogerontic Strophalosia and Aulosteges; that the characters of the neanic and ephebic stages of Coroniceras trigonatum are phylocatabatic" (here phylanagerontic). While granting the need of using this distinctive prefix for the periods of evolution in the phylum one is likely to become confused unless he fully understands the use of the word "phylum" as applicable to all grades of genetic series. Thus, in ordinary acceptation of the term, a phylum may be the entire class or any subdivision of it, even a single genus, provided the forms can be shown to be genetically connected. It has been employed in this way several times in this text after the names, species, genus, family, etc., the ammonoidal phylum or ordinal phylum, phylum of the Goniatitinae or sub-ordinal phylum, family phylum, and even a phylum of varieties and individuals.

The Cycle.

Phylum expresses genetic connection, cycle the totality of the phenomena, whether morphic or physiologic, which are exhibited by ontogeny or phylogeny. Thus, one can describe the cycle of the phylum in its rise and decline, the epacme, acme, and paracme, as purely dynamical phenomena exhibited by the increase in numbers of forms, etc., or the cycle of the ontogeny as shown by the increasing complexity of the development and its decline, the anaplasis, metaplasis, and paraplasis of the individual; or one may describe the cycle as exhibited by the embryonic, nepionic, neanic, ephebic, and gerontic stages, or the cycle of the phylogeny as exhibited by the corresponding stages of evolution designated by their appropriate prefix "phyl."

There appears to be real need of two terms under the head of cycle, one for ontogeny and the other for phylogeny. It is proposed to use in this way ontocycle or ontocyclon for the ontogeny, meaning the cycle of the individual, and phylocycle or phylocyclon for that of the phylum. This will make it practicable to use the terms monocyclon or monocyclic, polycyclon or polycyclic, etc.,

to describe the number of cycles observed. Thus the ammonoids are polycyclic, the Arietidae are decacyclic, the genus Coroniceras is an incomplete monocycle.

It is not necessary to defend these terms before students of bioplastology: they will be tested and if convenient adopted. For the benefit of others it may be mentioned that the cycle is of all degrees of development in ontogeny. Thus, Insecta are apt to stop at the ephebic stage and in many other animals there is a similar limitation. On the other hand there may be the most unexpected development of the cycle. Thus, Podocoryne starting from the hydroid stage passes through a permanent colonial stage built up by budding which gives rise by secondary buds to independent medusae. The life of an independent medusoid bud ends with a paragerontic substage in which the veil is destroyed, the bell is partially resorbed and turned back together with the tentacles, and the proboscis is left naked and projecting. In this condition the old of Podocoryne is similar to the hydroid with which the colony began. This herontic transformation has been observed by Dujardin in Cladonema and Syncoryne, by Hincks in Podocoryne and Syncoryne, and by Gosse in Turris.[1]

Man is not completely ontocyclic but makes a close approach to this in the loss of the hair, teeth, and proportions and shape of the body; and certainly in some parts, as in the mandible described above, there is sometimes a completed cycle.

What the limits of the ontocycle may be has not yet been ascertained, but so far as the facts are known, it would appear to be coincident with the limits of agamic reproduction or in other words with the limits of the growth of one autotemnon or of one ovum after conjugation by fission, and includes all agamic generations produced by division or by budding.

The act of self fission is similar whether it takes place for a certain cycle among Protozoa or Metazoa under purely organic conditions or follows upon the conjugation of two zoons, and is due to the rejuvenation caused by the union of the nuclear elements of their bodies as among Protozoa or the more differentiated generative cells of the Metazoa. Under all conditions the cells divide in obedience to the laws of growth, and whether

[1] Dujardin, Ann. sci. nat., sér. 3, v. 4, p. 257–281, 1845: Hincks, British hydroid zoophytes, v. 1, p. xxviii, 1868.

the resulting daughter cells remain fastened together forming colonies as in Protozoa or masses of tissue as in Metazoa, or whether they separate and become distinct autotemnons or distinct zoons the action is the same.

The product of this autotemnic function in single cells has, as shown by the researches of Maupas, a cycle of transformations which are like those of an individual among Metazoa, although they may reach in some forms over six hundred so-called generations and therefore include thousands of distinct protozoans. It is obvious to the student of bioplastology in reading Maupas's researches[1] that this cycle among Protozoa Ciliata, is the equivalent of the cycle of the individual among Metazoa. Although he uses the word individual for the autotemnon, he does not speak of the successive forms as generations but as partitions, "bipartitions" being his usual term, showing clearly that he recognizes these are not generations like those of distinct successive zoons in Metazoa.

Maupas's researches show, as in fact he himself states, that there is a cycle of partitions produced from one autotemnon after conjugation, when isolated and allowed to propagate by fission without the renewed stimulus of conjugation with others of different broods. The earlier successive partitions are incapable or at any rate do not show any desire to conjugate with their fellows. Each of his cultures of isolated autotemnons passed through these youthful or anaplastic stages, and then a series of metaplastic partitions was developed in which the micronuclei became more numerous, and conjugation with other broods took place whenever it was permitted by the experimenter.

In the generations immediately succeeding, these degenerative changes, both structural and physiological, took place in the partitions which were distinctly paraplastic, although the cultures were maintained under conditions which precluded the supposition that these changes could have resulted from unfavorable, abnormal surroundings. The successive partitions then had gerontic transformations, lost their micronuclei, became much reduced in size and unable to conjugate with others with the usual normal results, and finally the external buccal apparatus was affected, reduced, or

[1] Recherches expérimentales multiplication des infusoires ciliés, Arch. de zool. expér. et gén., sér. 2, v. 6, p. 165–277; *ibid.* v. 7, p. 149–517.

obliterated, and so on. These changes were termed senile by Maupas, who explains the entire phenomena as a cycle comparable with that of the individual among Metazoa.

One is of course at this incipient stage of bioplastology confused by many apparently inexplicable phenomena. When it is remembered, however, the confusion of the most eminent authorities with regard to the relations of the autotemnon among Protozoa and Metazoa, shown by the use of the same term for the autotemnon, the individual, and the zoon, and also the prevalent confusion with relation to the morphology of forms designated as colonies, some regarding the whole product of one egg as an individual and others considering each bud or independent zooid as properly designated by that term and defining the colony as a aggregate of more or less connected individuals, it is surprising that there should not be more difficulties in the path of this new branch of research.

Those who try to find the cycle of metamorphoses in their own special branches of research will be often disappointed and probably deny that it exists at all. Thus in my own case, I for some time could not find any evidence of its existence among certain cephalopods, notably those having a primitive organization like Endoceras and Orthoceras; but I have since seen well marked senile stages in these shells. Undoubtedly there is as great distinction between the paraplastic and anaplastic periods, and between phyloparaplasis and phylanaplasis everywhere, as there is between the correlations of the corresponding periods at the extremes of the ontogeny and phylogeny.

Paraplasis essentially differs from anaplasis, as has been described above in treating of relations of analogy between the gerontic and the nepionic stages. The earlier characteristics of ontogeny are, as the author has striven to explain in several publications, essentially distinct, being in large part in most animals and in some cases almost wholly genetic. In considering the simplest manifestations of the cycle, palingenesis accompanied always by tachygenesis must be taken into account and also cenogenesis in groups like Lepidoptera, Hymenoptera, most Echinodermata, many Vermes, where a supposed ancient

and regular palingenetic record is assumed to have been disturbed by ctetic characters acquired by the larvae.[1]

The gerontic characters on the other hand and all paraplastic as well as their corresponding phyloparaplastic characters belong to the category of analogies in so far as they are purely morphic resemblances or equivalents. This is clearly shown in the physiology of all the parts and organs in the anaplastic and paraplastic periods, the former being full of hereditary and perhaps also acquired power and the latter more or less weakened and reduced or worn out by the exercise of those powers and the constant wear and tear of the surroundings.

Retrogressive reductions in every form, although often indicating and accompanying a high degree of specialization, partake more or less of the same nature when considered with reference to their morphic and accompanying functional attributes, and one cannot study such bioplastic phenomena as if they were of the same nature and subject to exactly the same laws as progressive genetic and ctetic characters. As I have pointed out above and in several other publications, there are all degrees of completeness in the evolution of the cycle, and it is dependent upon a variety of causes whether occurring in the ontogeny or phylogeny. If it were constant and invariable and independent of the surroundings in the phylum, it would not be so closely parallel to the ontogenic cycle, which we know to be subject to great variations in accordance with the surroundings of the individual or species.

The standard of reference in bioplastology is the ontogenic cycle, and this should be studied first in every group. Without

[1] Such examples are, correctly speaking, not disarrangements of palingenesis although so translated by Haeckel, if I rightly understand his ideas of a confused record. Cenogenism does occur in such examples in obedience to the same law that governs palingenesis, but it occurs through the introduction of ctetic characters during the larval instead of in the neanic or ephebic stages, and the crowding back of these upon the nepionic and embryonic stages. The use of terms indicating that nature has confused or destroyed its own ontogenic records of the transmission of characters in certain cases assumes, (1) that these are exceptional cases; (2) that cenogenesis is not the normal mode of transmission in certain types in which it occurs; (3) that both of these modes of transmission are not affected by tachygenesis; all of these implications being erroneous according to the opinions expressed above. One can assume a disturbance or perturbation, or decided change of mode according to law, but "destruction," "confusion" or "falsification" are subjective terms inapplicable to the objective character of the phenomena to which they are applied. (See also note on p. 78.)

a full knowledge of this, the morphology of the group cannot be properly translated, nor can the forms be taxonomically treated with reference to their natural relations. This branch of research aims to complete Von Baer's law and Louis Agassiz's great discovery of the correlations of palingenesis and phylogenesis, and it, therefore, asserts an equal utility for the metamorphoses of the nepionic, neanic, ephebic, and gerontic stages, provided these be applied in each group according to the ontogenetic development of the cycle in the zoon and its phylogenetic evolution in the same group.

Stages of Morphogenesis.

As remarked by Buckman and Bather, "it is possible to trace the evolution of one character from its first appearance to its final loss, right through the history of a long line of individuals." They also say, "the various characters that go to the formation of an individual or a race, at any period of its development, may themselves differ greatly from one another in the degree of their own development." And further, "for the designation of the successive stages in the history of a character, the ontogenic terms might be used with the addition of the prefix morpho—*e. g.* morphobrephic [here nepionic], morphephebic." These suggestions are certainly useful, but they appear to me to cover both ontogeny and phylogeny, while according to the title used by these gentlemen, " Stages of individual morphogenesis," they were meant to apply only to ontogeny.

If one traces the history of any one character, something which every student of bioplastology must habitually do in actual practice, throughout a chain of individuals whether these are members of one variety or one species, or whether they lead into distinct species, as they are apt to do, he is studying the phylogeny of that characteristic. It would seem therefore that the prefix "phyl" would be applicable in such cases, whereas the use of a single term for both the phylum and the individual, especially the prefix "morpho," would be likely to confuse.

It follows from the principles of bioplastology that no consideration is here given to transient characters or those having no genetic meaning. It is, however, quite possible, although I have no experience to call up to illustrate this statement, that charac-

teristics of this class do run a certain limited cycle of changes and then disappear. In that case investigations would be required to establish the facts and also to determine whether they should be considered as coming under the head of bioplastology or ctetology.

Within my limited experience there are no fixed characteristics which do not obey the laws of bioplastology. Those appearing sporadically in individuals or those plainly due to locality or some habits, which are not perpetuated in the race or phylum after the causes that gave rise to them have ceased to act, have been more extensively studied by others and I must leave such questions to them.

Relations of the Nomenclatures of Taxonomy and Bioplastology.

Prof. J. F. Blake proposes[1] abandoning the terms "genera" and "species" and apparently the whole terminology of taxonomy, and it is evident that some discussion of the relations between binominal nomenclature and that already employed in bioplastology or proposed in this paper is necessary.

This learned authority has given generous praise to my work and his good opinion has been very gratifying to me. He has also been justifiably frank in his criticisms, and on some points, as upon that of nomenclature, we are not in accord.

In support of the revolutionary opinion cited above he makes a distinction which does not in my opinion exist. Thus, after speaking of the distinction between the genus of contemporaneous species and the lineage of "successive forms", he states, "Unfortunately Hyatt still uses the word genus at great risk of confusion for a single genetic line," and then quoting from my Genesis of the Arietidae he adds, "The unit of classification is, therefore, not the species but the genus; in other words, it is the smallest natural group which is genetically connected, and in which a more or less complete cycle of forms or species may be traced. In such a system, also, certain radical forms which do not show the usual morphogenetic cycle may occur. These may have a closely allied and inseparable series of varieties, which cannot be distrib-

[1] Evolution and classification of Cephalopoda, Proc. geol. assoc., v. 12, p. 80 et seq. and 295, April, 1892.

uted into the different genera arising from them. In such cases the radical may be considered as an undeveloped series and separated as a distinct genus, though it consist of only one species with well-marked varieties." "All we want to alter in this," says Professor Blake, "is to substitute 'lineage' or some equivalent word for 'genus' and 'form' or 'mutation' for 'species.'"

The objection made by Professor Blake rests on the assumption that a genus may be defined to be a group "of contemporaneous species." This term as used in botany, zoology, and paleontology is obviously a convenient name for a group of organic forms, called species, which are unitable by common characteristics. The common use of the term "genus" and also that of "species" includes no reference to time, to location, or to any theoretical connections that may be made between the organisms.

The opinion that the employment of old words in new senses increases the difficulty of all scientific exposition by obliging the mind of the reader or student to act in opposition to fixed habits of mental association, has been upheld in this paper. It has also been tacitly assumed, that the effort to assimilate a new word is slight compared with that required to enlarge the meaning of an old term, involving as it does two distinct mental operations. Such remarks, however, can be legitimately applied only to terms having acquired a more or less fixed definition and application.

The terms of binominal nomenclature in organic research are, however, elastic verbal structures of a different class. The terms genus and species have never acquired a fixed definition and like those of all other categories of taxonomy have been perpetually changing in application. There has been of course a steady gain in the mode of regarding the species and genus, in so far as the progress of knowledge has led naturalists in every department to construct their classifications more and more in accord with the natural relations of organisms.

They have been used by every writer as an elastic medium for the expression and explanation of the results of his researches into the relations of forms. Thus, in my own researches I have arrived at what I think is an approximately satisfactory definition of a genus and do not see what is to be gained by calling this class of groups by another name, as the old term genus seems to fit exactly. The use of the word "genus" calls attention to the very fact that I wish to insist upon, *viz.*, that this is a novel and natu-

ral definition of the genus as opposed to the older and more artificial definitions of the same taxonomic term.

The definition of genus quoted above does not mean that one must necessarily follow out in time the evolution of every genetic cycle which can be classed as a genus. On the contrary it means simply that having established the occurrence of such cycles in any given group, and having ascertained the morphic range of the cycle in that group, one can apply the knowledge thus gained to the estimation of the value of any series of species of the same group exhibiting similar relations, whether these occur together on the same level or not.

The inference is, of course, that the forms exhibiting such a morphic cycle or any part of such a cycle, did come from some common ancestor and arise successively in time. This inference, however, does not exclude the holding of an opposite opinion.

If the fact is granted that several genetic series or even one in a group goes through with a cycle of morphogenesis which accords with that of any individual in the same series, there is a standard established and a twig of the genealogical tree can be clearly seen from its origin to its end formed by successive species. Taking this measure we can apply it to the estimation of the affinities of any similar series, whether this has been evolved slowly in time, passing through several beds or stages, or has arisen by the migration of species from one basin or fauna to another on the same geological horizon, or has been produced with such extreme quickness, as in the degenerative series of many Ammonitinae, that all are found in the same locality and practically on the same horizon.

Suppose even that it should be proven, or that some investigators believed that such local series did really arise, as they often seem to do, at once from a common radical on exactly the same levels and simultaneously, and yet retained the aspect of a cycle, having some species which were phylonepionic, others phyloneanic, phylephebic, and even phyloparagerontic. The cycle or part of a cycle thus formed could be united as a genus and the relative position of every species properly and clearly designated.

There are some generic series of forms occurring simultaneously in geologic time and in the same locality, which have heretofore been supposed to be evolved in the same way as more extended series, the species of which occur in succession upon

different levels; there are also series of larger groups arising simultaneously, spreading out like the spokes of a fan from a common form. That cycles may have been formed in this way through the action of the surroundings upon a common organism, either by simultaneous genesis of forms or so closely simultaneous that the element of succession in time was obliterated, is a statement that can be supported by a certain series of facts of observation. Although one should be wary of admitting such a view, it is a thesis which can be well supported, and in fact has been directly maintained by Neumayr and others in the theory of polygenesis.[1]

If it were to be established that a cycle could be thus generated, it would not invalidate the definition here advocated. The only fact that would make it useless, so far as the genus is concerned, would be the discovery of phylocycles in the species, because in this definition it is said to be "the smallest natural group which is genetically connected, and in which a more or less complete cycle of forms or species may be traced."

Professor Blake's nomenclature, however, so far as he has sketched it, certainly does point to a possible improvement in the explanatory nomenclature of groups which would be of great assistance, although not, as suggested by him, of such primary importance as to form a good substitute for the established categories, genus, species, etc.

The application of definite popular terms to certain subdivisions which would at once explain their significance in the evolution of the whole group to which they might belong, would be extremely convenient. Thus, among the Arietidae I found it useful to call the common point of origin of the family, the genus Psiloceras, "the radical stock," and the different genera that sprang from this in radiating lines according to their general genetic relations by other names; the plicatus stock included the genera Waehneroceras, Schlotheimia, Caloceras, and Vermiceras, and the levis stock included the genera Arnioceras, Coroniceras, Agassiceras, Asteroceras, and Oxynoticeras.

In order to make my meaning with regard to these groups still clearer, I also defined each genus by the word series. Thus, under each stock in the general descriptions of the genetic rela-

[1] See Genesis of the Arietidae, p. 118.

tions I designated each genus as a series not as a genus, thus the genus Schlotheimia appears there as the schlotheimian series, Caloceras as the caloceran series, and so on. This application of explanatory terms seemed to me to make clearer the new meaning which it was proposed to give to the accepted taxonomic terms, and furnished a set of parallel, popular designations which in certain cases could be used in place of the scientific names of the genera.

In this process the word "stock" was substituted for what would ordinarily have been termed a subfamily. Thus, the plicatus and levis stocks distinguished by the peculiarities of their young are really equivalent to two subfamilies in my classification, and their taxonomic equivalent is the radical stock which, however, consists of only one series or genus, Psiloceras. In so far as such terms may be sometimes substituted for such highly artificial subdivisions of standard groups, their use seems to be unobjectionable and even an improvement, since they express different ideas of relation, and substitute natural for unnatural associations. Nevertheless, they are essentially explanatory terms which can be used side by side with ordinary artificial terms of taxonomy and serve to help out the diagnoses.

Mr. Blake proposes the term "mutation" or "form" for "species" and "lineage" for genus. It is hardly worth while to give a new meaning to "form." This is a very useful old word and without it as a staff to lean upon in general description one would often be at loss for an expression, but "mutation" might be very well used to explain a change taking place in a generic series which is of specific importance. The terms "variation" and "variety" have an already accepted meaning and are strongly entrenched in the literature of evolution as applied to groups of subspecific value.

The substitution of "lineage" for series, which I have already used for the genus, is perhaps necessary. The term series, being suitable for general use, should not be restricted to any special category of forms, and I shall hereafter adopt Professor Blake's substitute.

In the Genesis of the Arietidae I have used the explanatory term "branch" where it seemed essential to unite two series of any one stock for descriptive purposes on account of their junction near the radical stock. This term has there been used in the same

general application as the term "tribe" used by many naturalists for associating related genera in a subfamily, and for obvious reasons it is perhaps better to abandon the word "branch" as used in this way for the more commonly used term "tribe" and transfer "branch" to the suborder.

In working upwards the next main subdivision is of course the family. The family in terms of bioplastology, as shown in my former publications, is an assemblage of genera or series arising from a common radical stock.

The application of a descriptive term to a suborder is of equal importance to that of the family. This is also, together with the order and class, one of the terms which according to Professor Blake applies only to associations of contemporaneous forms. I presume that this idea is founded wholly upon the original use of these terms among living organisms, but they were found to be equally applicable in paleontology when research began in this branch of science and have become established in the literature. I do not consequently understand why they cannot take the next step and be equally convenient and significant in bioplastology. Their artificial meaning as translated by many naturalists is certainly a serious objection, but the next generation is not likely to have the same restricted views, and any attempt to disturb terms so elastic as these and so well established in the literature of natural science will do more harm than good.

The suborder among fossil cephalopods is a remarkably significant group in the evolution of the orders and serves to show us the larger cycles in time by which this is accomplished, as well as the decisive steps which occur in the progressive history of the structures and organs. The phyloparagerontic and terminal forms of genera of these suborders are often also excessively degraded. Thus, the Goniatitinae, Clymeniae, Arcestinae, Ceratitinae, Lytoceratinae, and Ammonitinae form a grand structural series of steps in the evolution of the order of ammonoids, and each one is a definite advance in progression. At the same time they have within their own limits highly degraded forms such as occur in Ceratitinae in the uncoiled Choristoceras, the turritelloid shell Cochlioceras, and the straight cone of Rhabdoceras. It is not at all unlikely that similar extreme cases may be eventually found in the other suborders since similar phyloparagerontic forms are also found in Ammonitinae and Lytoceratinae. They are distinct

branches springing from the ordinal phylum and forming constituent parts of it at their origin but diverging above, and each having its own independent lines of modifications terminating in space and time according to their own morphic cycles. The term "branch" could be very appropriately used for these suborders and they could thus be spoken of as the branches of the order.

The orders are more or less complete cycles of suborders and we see no reason why the order, whether thought of in the artificial light of the old school or that of the new, is not as applicable in paleozoology as in zoology. If a descriptive adjunct implying a dynamic character is required, the term "limb" could be appropriately employed. The orders of Cephalopoda can be recognized as closely converging in the case of the ammonoids, nautiloids, and belemnoids. The sepioids may be convergent with belemnoids, but the exact type from which they may have originated has not yet been pointed out.

The ephebic structures, and the embryonic and nepionic characteristics of nautiloids, ammonoids, and belemnoids present strong internal evidence of having been derived from a common type which must have been an ancient, straight form of nautiloid with a small siphuncle and this siphuncle composed of two parts, the funnel and the sheath.

The Orthoceratidae, therefore, are the only paleozoic type or "trunk" form to which the orders of Cephalopoda, the limbs of that genealogical tree, can be approximately traced or referred, this being the only ancient microsiphonulate group with a straight shell. The arguments for this position have been given in detail in Genera of fossil cephalopods and in Genesis of the Arietidae, and recent investigations have confirmed this opinion. It would therefore be appropriate to consider this family as the "trunk" of the class of Cephalopoda.

Orthoceras can in its turn be definitely traced to the Endoceratidae. This family and the Actinoceratidae, the parallel group of the Paleozoic, must have had preceding ancestral forms in the Coecosiphonophora and Protosiphonophora corresponding to the coecosiphonula and protosiphonula of the ontogeny. These last named two families, therefore, are not trunk forms like the Orthoceratidae, or limbs like the orders giving off branches in the suborders, but constitute the roots of the trunk

forms. This important fact cannot be too much insisted upon, especially when taken in consideration with the important differences of structure that exist in these families. They have not only the huge siphuncles composed of long septal funnels instead of the short septal funnels of Orthoceras and the remaining Nautiloidea, but they have the additional primitive more or less septate endosiphuncle and a distinct nepionic substage. The ananepionic shell had a deep, more or less circular or funnel-like impression on the apex, which is usually plugged or discontinuous internally. The endosiphuncle arises from the internal side of this involution of the apex, and there is reason to believe that there was continuous open connection between the two at an early stage, as originally pointed out by Foord in his "Catalogue of British Cephalopoda." Whether this be so or not, it is obvious, according to the standards of classification here adopted, that these forms constitute a distinct order of cephalopods. I hope shortly to present the evidence for this in detail, having already sufficient on hand to illustrate all the opinions here given, and I hope to be able to show that the Endosiphonoidea, as I propose to call them, are quite distinct in internal structure from true Nautiloidea.

Whether this be granted or not, it is evident that all observations up to the present time show the Endosiphonoidea to have been the primitive ancestral or class radical of the Cephalopoda, whereas Orthoceras is the ordinal radical of its own order and also the trunk of the separate diverging orders or limbs of the ammonoids and belemnoids.

"Radical" is a very convenient descriptive term and I have used it extensively in order to indicate any form that may be considered as having given rise to others. Among Brachiopoda, Beecher has clearly pointed out that Paterina is a class radical, and Jackson that Rhombopteria is a similar class radical in Pelecypoda, and Brooks that the Scaphopoda are very likely the subkingdom radical for all classes of Mollusca, or the molluscan radical.

SYNOPSIS.

term series given up to general use, 119; term branch supplanted by tribe equal to subfamily, 119-120; term family, 120; suborders wrongly defined by Blake, 120; significance of these groups, 120; branch used for suborder, 121; term limb proposed for order, 121; the limbs of the Cephalopoda spring from the Orthoceratidae, 121; this family is therefore the trunk of the class, 121; the Endoceratidae the roots of the Cephalopoda or radical forms, 121-122; preliminary description of the Endosiphonoidea, 122; term radical, 122; other radical forms, 122.

Mr. W. F. Ganong spoke on the topography of plants.

General Meeting, April 19, 1893.

President W. H. Niles in the chair. Sixty-two persons present.

It was announced that the Council had elected John M. Coulter, Daniel C. Eaton, Angelo Heilprin, George H. Horn, Joseph Leconte, J. Peter Lesley, Henry F. Osborn, Richard Rathbun, Robert Ridgway, William Trelease, and Edmund B. Wilson Corresponding Members, and Albert Perry Brigham a Corporate Member of the Society.

Prof. H. W. Haynes, for the Committee on the nomination of officers for 1893–94, presented a report.

Mr. C. P. Bowditch, spoke of the ruins of Central America, describing various architectural structures, modes of burial, plans of plazas, monoliths, etc.

The following paper was read: —

ON TRACES OF A FAUNA IN THE CAMBRIDGE SLATES.

BY J. B. WOODWORTH.

[*Abstract.*]

In 1869, Professor Shaler gave the name Cambridge slates to the argillaceous and arenaceous rocks in the valleys of the Mystic and Charles Rivers, and announced the occurrence of obscure fossils or fucoids in this formation, but of these fossils no descriptions or figures were given.

The term Cambridge slates is used in this paper to designate the slates referred to by Professor Shaler, and also their extension in other parts of the Boston Basin where fossils similar to those found in the vicinity of the Mystic River occur. In general it may be said that the series of slates described by Professor Crosby as lying upon the Roxbury conglomerate fall into the Cambridge slate formation.

Trails consisting of a narrow medial furrow and lateral ridges occur on the upper surface of black shaly layers in Malden and in the Mystic River and Clarendon Hill quarries in Somerville. Similar trails are made on the beaches of Boston outer harbor, at the present time, by the isopod crustacean, *Idotea irrorata*. Pitted impressions, isolated, in groups, or in pairs, resembling the worm-borings known as Arenicolites, also occur widely distributed in the formation, but cross-sections of the slate generally fail to show the U-shaped tube on the existence of which the annelid origin of the impressions is determined. A cup-shaped depression resembling the form known as Monocraterion with a central vertical tube was found by the writer in the slate of Beacon Street in Newton Centre. A jointed trail from West Somerville, Mr. Walcott thinks, is probably that of an annelid.

A single cast lying in the bedding plane of the slate in the Mystic River quarries of Somerville suggests a species of Hyolithes, but this and the forms above described are too indefinite to afford a determination of the age of the slates.

A series of transversely striated trails or impressions of problematical origin has been collected from the slates at Malden and near Norfolk Down's station in Wollaston. Similar specimens were collected from the last named locality several years since by Professor Shaler. A discussion of these and other problematic fossils in the formation will be given in a forthcoming paper, in the Bulletin of the museum of comparative zoology.

The fossils thus far found indicate that we have in the slate series one of those barren sections carrying annelid or crustacean trails, which occur in various horizons of the Paleozoic. The occurrence of shrinkage cracks and ripple-marks in the zones carrying these trails, together with the increasing amount of arenaceous sediment towards the west, indicates tolerably shallow water during the deposition of the slates.

Annual Meeting, May 3, 1893.

President W. H. Niles in the chair. Twenty-seven persons present.

The following reports were presented:—

Report of the Curator, Alpheus Hyatt.

The past official year has not been marked by the occurrence of many events of importance which can be advantageously noticed in the introduction to this report, and yet the Society as a whole has never been more active or made faster progress.

The new By-Laws, which have guided us this year, were not regarded with favor by some members on account of the radical changes introduced by their adoption, but the business of the Society has been conducted with more ease and promptness by their aid than by the older system.

The resignation of Mr. Samuel Henshaw as assistant in the Museum, in the month of October, deprived that division of the services of a faithful and remarkably efficient officer who for many years had served us in general charge of the collections. It was not found practicable to fill this vacancy immediately, and the amount of work done in the Museum has been considerably lessened on this account.

It is to be regretted also that the Museum has temporarily lost on account of absence from the country the services of Mrs. Ramsay who worked so effectively upon the collections of microscopical materials last year.

We are indebted to Mr. John Cummings, Mr. C. B. Cory, Mr. T. A. Watson, Miss J. M. Arms, and Miss E. D. Boardman for their voluntary labors in our collections which are again noticed below under the proper headings.

As in years past, our Museum has been used by classes from the Institute of Technology, and more or less by students coming separately to study in the collections on closed days. Permission to visit and study in the Museum on days when the public is not admitted has been granted to eleven teachers, representing thirteen schools and two hundred and seventeen pupils.

The practical completion of the collections in the departments of mineralogy and geology brings the Society to a turning point

in its history. The funds invested in these collections and the labor given to them have been justified by the original results of Mr. Crosby's investigations and by the usefulness of the method of arrangement, but they ought to serve still another purpose. They show what can be done with other departments of the Museum, and how unique and useful our educational collections would become if all of them were completed according to the same plan. In other words they ought to be used to attract the attention of those who can help us to complete our Museum and do similar work in other departments. The zoology and botany of our own region should also be worked up in a similar way to the geology, and the results published in series of memoirs. The plan of this Museum contemplated in every department such work as has been done by Mr. Crosby in mineralogy and geology. It was supposed that the continuous doing of good work would be sufficient to raise and multiply friends who would be both willing and able to help us make other departments as effective as those of mineralogy and geology. As a matter of fact, however, the attention of those who can help us cannot be gained except by direct solicitation, and the sooner it is begun the better.

Teaching in the Museum.

No change has been made in this department since last year when a full account was given of the mode of instruction.

The attendance has been about the same as during the preceding year.

We are still without the means of heating the Museum and consequently cannot make the collections useful during the colder part of the winter. Although we keep the Museum open for two days in each week during the entire year, it is, so far as its real use by visitors is concerned, practically closed for four months, from December to March inclusive.

A movement to raise the necessary funds to put in heating apparatus and pay for the annual expenditure of coal and so on, has been begun, but it is felt that this would be incomplete, unless the amount raised were also sufficient for the salary of the guide who alone can really make the opening of the rooms of educational

value to the majority of the visitors. Unless these two objects could be combined, the opening of the Museum during the coldest months of the year would probably not have very beneficial results and might serve to make it a place of refuge for a certain number of homeless idlers.

The Society owes the existence of this department to the generosity of a member who hopes with the Curator that the success of the guide's efforts in the Museum may lead to the inauguration of an organized effort to raise the funds necessary to acomplish these objects.

Dynamical Zoology.

The Curator spent all of the summer months and a considerable part of the winter in redescribing the species and working over the Gulick collection of shells. In spite of the large amount of time already expended in this direction, it will probably take several years more before the shells can be mounted upon the relief map of the Island of Oahu. In consequence of redescribing every variety and every species of the shells and verifying all the details of their affinities, this work has grown to the dimensions of an original research involving the writing of a memoir on the Achatinellinae.

The Curator has also prepared a large plate to illustrate the evolution of the Arietidae, and Miss Martin has drawn the figures for this plate, but the method of mounting has not yet been settled upon.

The slow progress of this department is owing to the need of constructing original examples of this kind and the costliness of the specimens desired, but more than all else to the difficulties attending the collection of specimens and the construction of the reduced models of larger animals.

Geology.

The Guide to dynamical geology and petrography, which went to press last April, was finally issued in October; and during the year the labeling and final arrangement of the collections to which it relates have been completed.

The general collections in both mineralogy and geology may now be regarded as for the time being in a finished and satisfactory state; but in consequence of the natural growth of the collections and the progressive development of geological science, both the arrangement and the text will require revision from time to time. In fact, a revision of the mineralogical collection and Guide has been in order for some time, especially since the appearance of the new edition of Dana's System of mineralogy, and it should be undertaken within a year or two.

In the meantime, it appears desirable to make such progress as we can with the New England and local collections.

The New England collection of minerals is growing slowly by means of occasional donations and the personal efforts of the assistant, but it is still far from complete.

A comprehensive and creditable illustration of the geology of New England would be impracticable for want of space, even if the materials were sufficient, but we are gradually accumulating these and temporarily placing the specimens on the shelves in the gallery of Room B.

The outlook for the local geology — the geology of the Boston Basin — on the other hand, offers more encouragement. The materials needed for this purpose are all within easy reach, and the limits of adequate representation do not so greatly exceed the space at our command. A large proportion of the assistant's time during the past year has been devoted to investigation in this direction; and the Curator in behalf of the Society takes great pleasure in acknowledging the important aid which has been received from Mr. T. A. Watson. Besides assisting in the field work, Mr. Watson has contributed the funds for the publication of the results of this work. The printing of the monograph on the geology of Nantasket and Cohasset, which had been suspended, was in consequence of this encouragement resumed last September, and has been completed. It embraces 177 pages of text, two large colored maps, and thirty cuts.

The second monograph of this series, on the geology of Hingham, of which an abstract was printed in the Proceedings, is nearly ready. The three colored maps for this second monograph are already printed. Mr. Watson has again shown his interest in this work by contributing the services of a draughtsman who has drawn the general map for the third monograph, on the

geology of Weymouth, Braintree, and the Blue Hills. Miss Martin has also made a number of illustrations for this department.

Botany.

This department has been cared for this year, as during many previous years, by our veteran benefactor, Mr. John Cummings.

Miss Carter has completed the final revision and cataloguing of the general herbarium by the revision and cataloguing of the Algae. This class is represented by 353 genera, 1406 species, and 3748 specimens. These figures added to those given in last year's report upon this department give the sum total of our collection of cryptogamous plants as consisting of 10 orders, 932 genera, 5189 species, and 11,323 specimens.

The collections of woods, fruits, etc., have also been carefully revised, and the set of woods given by Mr. Charles B. Brooks has been properly catalogued and labeled.

The following accessions are hereby acknowledged: Mr. Chas. B. Brooks, 275 specimens of wood; Mr. Nathaniel T. Kidder, a very rare and interesting specimen of Conopholis americana, showing undeveloped buds parasitic on oak; Mr. E. H. Hitchings, herbarium specimen of Conopholis americana for New England collection; Mr. W. S. Rhodes, one specimen for New England collection; Miss Cora H. Clarke, 8 specimens New England Algae; Miss M. K. Goddard, one specimen New England Algae.

Nineteen persons have been allowed the special use of the herbarium, and more time has been asked for and given to this work than in previous years.

Synoptic Collection.

Miss J. M. Arms has continued her voluntary labors upon this collection, the immediate object of which was described in the last report.

The descriptive text of the Porifera has been practically finished. It consists of 70 pages of manuscript. The class of Hydrozoa is also in an advanced stage of preparation, the text being nearly finished.

Mrs. E. D. Ramsay has presented mounted specimens of Miliola, Orbitolites, Cornuspira, and some Foraminifera from Dover, England, and Kansas.

A number of colored drawings of Protozoa and Porifera have been made for this department by Miss Martin.

Paleontology.

Miss E. D. Boardman has continued her voluntary labors upon the collection of gasteropods from St. John's, and this important piece of work is slowly advancing.

Miss Martin has worked upon this collection in remounting some specimens and supplying new tablets.

Mollusca.

Mr. Henshaw has worked in this department, labeling and arranging the Janthinae of the Mayo collection and about one hundred Murices and two hundred Cones.

Miss Martin has also worked more or less on this collection.

The Curator, besides the time expended on the Achatinellinae of the Gulick collection, has begun work upon the same group in our general collection.

Insecta.

Mr. Henshaw has taken care of the accessions, and also selected for the Society's collection several hundreds of specimens from the Holmes Hinkley collection, and has named and labeled them.

Ornithology.

Mr. Cory has continued to take care of this department, and has labeled and identified some of the species during the past year.

Laboratory.

The room in the southwest corner of the basement has been used as in previous years by three classes of the Boston University during the week, and by two classes of the Teachers' School of

Science on Saturdays. The room in the southeast corner has been given up to the storage of Mr. Cory's collections. Cases have been put up in the main part of the basement to receive the collection formerly stored in this room, and the specimens in these have been rearranged by Mr. Van Vleck.

The entire collection of diagrams, 600 in all, has been relabeled and numbered by Miss Martin and placed in new racks, making them more accessible than formerly. The collection of diagrams is constantly used by the department of biology in the Institute of Technology.

Teachers' School of Science.

This department during the past two years has become more closely associated with the interests of the teachers of the public schools than in its previous history.

The standing committee on elementary science of the New England conference of educational workers adopted this building as its regular place of meeting. This action, and also the results of the discussions of this committee, have shown that the leading minds in this part of the State, who are interested in science-teaching, have realized in a most gratifying way the past and present importance of the Society's work in this direction. There is an unquestionable revival of interest in the movement for the efficient teaching of elementary science in the public schools, which has been steadily gathering strength for several years, and which may be expected to develop still more in the immediate future.

All the courses of study carried on in this school for several years have been supported by the Trustee of the Lowell Fund, and the success of this important department has been in large part due to this fact.

The instruction given during the past year has completed the third of the four laboratory courses begun three years ago, and next year for the first time in the history of the school we shall turn out a certain number of persons who have had sufficient instruction to qualify them to teach the elements of mineralogy, geology, and botany. The School has educated very nearly all of the teachers who are now doing active work in teaching natural history in the

eastern part of the State and has pupils who have been incited to do this sort of teaching in all parts of the United States, but it has never before been able to direct its efforts for a series of years to the express purpose of preparing persons to teach different branches of Natural History.

The methods of work and examinations were described in the last annual report.

There are some very obvious facts in our late experiences. The demand for the proper sort of teaching in geology and botany is in excess of the seating capacity of the laboratories. The extent of this excess cannot be estimated, because no systematic attempt has been made to do so and because we have not needed to advertise the courses since the year in which they were begun. It is, however, perfectly plain that we could easily double, and perhaps treble, the number of those now attending these courses if adequate facilities could be offered.

The field course in geology by Mr. George H. Barton, referred to in the last annual report as the spring course and begun on April 2 before the expiration of the last official year, consisted of seven lessons and excursions ending on May 14. The average attendance was 27.5, and total number of tickets issued sixty. The similar course given in the autumn consisted of ten lessons and excursions into the field, beginning on September 24 and ending November 26. The average of attendance and total number of tickets issued were about the same as in the spring.

The spring course in geology for 1893 was begun by Mr. Barton on April 29, and is now in progress.

The winter course in historical geology, also given by Mr. Barton, consisted of seventeen lessons (fifteen being the required number) of two hours each, beginning December 3, 1892, and ending April 22, 1893. The whole number of tickets issued was sixty, and the average attendance was 46.7. This was the fourth course in a series consisting of mineralogy, lithology, petrology, and historical geology. The modes of study and other details were given in the last annual report, and the results this year were as satisfactory as those obtained in the preceding course.

Dr. R. W. Greenleaf's results have been so novel and remarkable that I give his report in full.

Thirty-five of the former members of the class in botany returned to their places, and fourteen new members were given tickets,

making 49 the total number at any time connected with the class, of whom three subsequently dropped out. The largest attendance was 46, the average 40.

A short written examination was held at the beginning of each exercise on the work of the preceding lesson. Thirty-four persons took the final examination, and their standing may be grouped as follows:—

10 had 90% or upward (two of these receiving 100% and two others 98%).

2 had 50% — 60%.
6 had 60% — 70%.
6 had 70% — 80%.
10 had 80% — 90%.

The exercises during the year were 15 in number, beginning November 5, 1892, and terminating March 4, 1893. They consisted of lectures followed by laboratory work, based entirely on our common plants. Numerous specimens were obtained from conservatories to illustrate the lessons and to help out the observations made upon the dried specimens, of which a set of one hundred kinds was given to each student. Blackboard diagrams and illustrations from monographs on systematic botany were also freely used.

Dr. Greenleaf desires me to acknowledge his indebtedness for the success of the course to his assistants, Miss Jennie M. Jackson, Miss Helen Sharp, and Mr. Samuel F. Tower.

As the plan of the course marks a departure from the usual methods of botanical instruction, a brief account of it may be of sufficient interest for record.

The class consisted wholly of busy teachers nearly all of whom had a fair knowledge of the typical features of plant anatomy, and most of whom could find the name of a plant in an analytical key, indeed knew by name quite a number of our common plants, but, excepting a few who had studied at the "Annex" or similar higher institutions, none had any conception of the fundamental laws of plant relationship and were inclined to consider the study of systematic botany as drudgery.

The method of work was briefly as follows: the subject of "Evolution" was taken as a "working hypothesis." After giving some idea of the vast numbers of species existing today and in

the past, and the possibility of classifying them in several well-marked groups, Dr. Greenleaf explained and illustrated the interpretation of various points of similarity and difference by the laws of descent with variation. Special groups were then studied as types, their characteristic points of structure being quite thoroughly explained, and the class was requested to construct theoretically certain possible lines of variation. With these as a basis of comparison, the various related families were studied and their relationships thus given a real meaning.

For example, the lily family is chiefly characterized by having regular flowers with six parts in the perianth, six stamens, and a superior three-celled ovary. Four principal lines of possible variation are the following:—

1. Multiplication of parts; shown well in Alismaceae, the water plantain family.

2. Irregularity of parts; Pontederiaceae, the pickerel-weed family.

3. Adnation of parts; Amaryllidaceae.

4. Reduction in number of parts; *a*. with adnation, in Iridaceae; *b*. with adnation and irregularity, in Orchidaceae; *c*. with extreme reduction, in Gramineae.

These facts are of course well known to the systematic botanist, but they are generally considered too recondite to permit of class demonstration. They were not found so. On the contrary, their presentation was extremely simple, and the class have readily understood the problems presented, moreover were awakened to an interest in the subject which was worthy of remark.

Besides the exceptionally high marks and high average of attendance, 41 members expressed their wish to attend a course in continuation of the work already planned, if it be given another year. Moreover, several of the members found time to arrange their notes and specimens, accompanying them with charts and notes descriptive of affinity, in a manner most creditable to their authors.

The series of special courses in historical geology and paleontology was continued by the Curator. There were sixteen lessons of two hours each, beginning November 4, 1892, and terminating March 25, 1893. The whole number of tickets issued was thirty-eight, and the average attendance was twenty-five. The class

was smaller than last year, but on the other hand it had gained in quality what had been lost in numbers, so that the instruction could be placed upon a higher plane than during previous years. The results of the examination were even better than those obtained during the last year. The Curator desires to express his thanks to Dr. R. T. Jackson and Miss J. M. Arms for assistance in giving these lessons.

Report of the Board of Directors of the Natural History Gardens and Aquaria. Samuel H. Scudder, Chairman.

The Directors of the Natural History Gardens and Aquaria have very little actual advance to report in the collection of subscriptions, the hindrances to the same being even much greater than was anticipated; especially so, since it has appeared absolutely essential that some alteration should be made in the conditions of subscription if we are to hope for success; and until some definite conclusions on this point could be reached, it has not been possible to accomplish much else.

Further inquiry into the methods by which Aquaria are managed elsewhere, and repeated examination of the water in the neighborhood of Marine Park under varying conditions, show us that it would not be well to depend there for indoor exhibits upon water pumped directly from the sea; but that it would be wiser to bring the water in casks from the open ocean and occasionally to replenish it, purification being maintained by proper aeration and filtration in the constant circuit. As soon as this was made clear, the question arose: Whether, in view of the main objection repeatedly made by those asked to give financial aid to the enterprise, it would not be well to seek a more central location for the Aquaria. It is true that we should then have to give up one attractive feature—the salt water ponds for the outdoor exhibit of the larger creatures and of shore animals; but by far the greatest difficulty we have had to contend with in trying to secure subscriptions has been the prospective location of the Aquaria at a considerable distance from the mass of the population, and one reached only by passing through a long stretch of a most unattractive part of the city. In time this may change to some extent;

but at present it is hardly a place where ladies and children can freely go unaccompanied.

The principal further difficulties in securing subscriptions have been, first, the natural doubt whether the enterprise can be made self-supporting even when the funds asked for are raised; and second, that while many persons of means are very ready to support such an undertaking by annual subscriptions of considerable amount. they are by no means ready to contribute an equivalent sum for the foundation of an establishment, the financial success of which they must consider problematical, because never tried under similar conditions. In short, they object to that feature of our plan which contemplates funding one-half of what we receive. Better, they say, ask us to give enough to erect and equip a simple building, and an annual guarantee of so much as is necessary to administer it for five years, and then at the end of that time, when the precise cost of what is needed for a permanent establishment shall have been demonstrated, ask for what may be shown necessary; or then let it pass as an experiment which has failed to show its public need, without loss to any but to those who have generously supported the undertaking.

The Directors have been profoundly impressed by these considerations, coming from men of affairs really interested in the success of our enterprise. And they believe they can offer a solution which may be the best means of attaining all and perhaps more than all that has been proposed in our plans for a Marine Aquarium.

There are two large rooms on the north side of the basement of the building in which we are met to-night, now occupied as store rooms; they are separated from the rest of the basement by a brick wall with two arched openings, easily closed; they may be entered from the street by the north basement door which leads into a vestibule between them. If the Society, through its Council, would grant to the Directors the use of this quarter of the building and remove its stores to another part of the large basement, these rooms could be fitted up at relatively small cost with Aquaria, both marine and fresh water, and lighted by electricity so as to be equally available as a place of resort and study day and evening. There is room for as many linear feet of aquaria as in the single room it was proposed to first equip in the contemplated structure at Marine Park. It would offer, therefore, at least outlay, all

that would be needed to show whether any further venture would be desirable, and just what would be needed. Twenty-five thousand dollars, half at the outset, half in annual subscriptions, would cover the cost of the undertaking, without further expense to the Society than the vacating of the required space, and without prejudice to the original plan for Marine Park, other than its postponement to await the result of this experiment. It is by no means certain that so long a period as five years would be necessary; nor that, once established here, the Society and the Public would be quite willing to see the Aquaria removed from this building when the larger exhibit was opened. One would have its greatest attractions in the summer, the other would be as available and as eagerly sought in the winter as in the summer.

The Directors submit this proposition to the Society, hoping for the favorable action of its Council; for until approved, subject of course to a successful appeal to the public, they can make no such appeal. The funds already in hand and certain pledges, both of which they believe will willingly be diverted in this direction by the subscribers, warrant them in thinking that this is the most feasible possible plan for the earliest consummation of our wishes.

Report of the Secretary and Librarian, Samuel Henshaw.

Membership.

During the past year eleven Corresponding and twenty-three Corporate members have been elected by the Council. Two Honorary members, Sir Richard Owen and Prof. J. O. Westwood, and three Corresponding members, Prof. J. S. Newberry, Dr. Henry Wheatland, and Daniel Wilson have died; one Corporate member has resigned, eight have died, and the names of eleven have been dropped for non-payment of dues. Among the Corporate members who have died mention should be made of Messrs. G. W. Bond, M. D. Ross, and the Rev. R. C. Waterston.

The roll of the Society includes the names of 17 Honorary, 146 Corresponding, 338 Corporate, and 20 Garden members, a total (less names counted twice) of 510,

Meetings.

Fourteen meetings have been held. With a total attendance of 860, the average over 61 to a meeting is less than that of last year, when it was a little less than 64.

The largest attendance at any one meeting this year was 95 the smallest 31; the largest last year was 121 and the smallest 28. Thirty-nine communications have been made by twenty-nine persons.

Library.

The most noteworthy announcement in regard to the library is the gift of $5,000—received from Miss B. L. Randall, executrix of the estate of our late member Dr. John Witt Randall, the income of which according to Miss Randall's wishes will be used for the increase of the library.

The additions to the library are as follows:—

	8vo.	4to.	Folio.	Total
Volumes	331	48	1	380
Parts	1,458	494	2	1,954
Pamphlets	317	29	1	347
Maps			16	16
			Total,	2,697

The total 2,697 is nearly 300 more than the average for the last ten years. The library consists of 20,551 volumes, 1,211 (incomplete including current) volumes, and 9,600 pamphlets.

To Miss B. L. Randall and Mr. James M. Barnard we are especially indebted for a number of books.

New exchanges have been arranged with seven institutions, as follows, Minnesota geological survey; Iowa academy of sciences; Rassegna delle scienze geologiche (Rome); Société des sciences naturelles de l'Ouest de la France (Nantes); Laboratoire de géologie de la faculté des sciences (Caen); Société scientifique du Chili (Santiago); Royal gardens (Kew).

By purchase we have added three serials, Natural science, Entomological news, Journal of geology.

The number of scientific societies and periodicals at home and abroad with which the Society now exchanges its publications is 372.

Nine hundred and ninety-five books have been borrowed from the library by 103 persons, 220 books have been borrowed for use in the building and the library has been consulted 522 times.

One hundred and eighty books have been bound.

A new method of charging books loaned from the library has been introduced; the change facilitates the ready location of a book and gives greater security to the library in case of loss; thus far it has worked successfully.

A rearrangement of the maps has been begun and some progress made towards indexing the papers published in serials A list of the 18 serials, 245 volumes, indexed is as follows:—

Academy of natural science of Philadelphia, Journal. (2d ser.).	9 vols.
American entomological society, Transactions.	19 vols.
Boston society of natural history, Anniversary memoirs.	1 vol.
Boston journal of natural history.	7 vols.
Memoirs.	4 vols.
California geological survey, Reports.	6 vols.
Challenger expedition reports.	36 vols.
Connecticut academy of arts and science, Transactions.	9 vols.
Journal of morphology.	7 vols.
Museum of comparative zoology, Memoirs.	17 vols.
Novara expedition reports.	21 vols.
Pacific railroad reports.	12 vols.
Smithsonian institution, Contributions to knowledge.	27 vols.
Miscellaneous collections.	33 vols.
U. S. entomological commission, Bulletins.	7 vols.
geological survey, Bulletins.	14 vols.
Reports.	10 vols.
(Hayden's) Bulletins.	6 vols.

If the card catalogue is to be the directory of the library, it is very essential that the contents of the various journals, etc., should be easily accessible. The problem of a subject index, or the business portion of the directory, is still to be attacked.

As all do not realize the amount of work essential before a book can be placed on the shelves, it may not be uninteresting to note that after the leaves are cut, the pages and plates are collated, an entry made in the accession catalogue, this entry indexed

for reference, title entered on the shelf list and written in full for the card catalogue with the necessary cross references, a book plate and library digest affixed, location decided and indicated, title-page stamped with the Society's name, and the plates stamped. Most of our foreign exchanges are received through the Smithsonian Institution and are accompanied by a blank to be signed: this blank has to be compared with the book and the record of the sender and an entry made in the exchange record, the exchange record indexed and finally an acknowledgment sent for all donations.

Publications.

Parts 3 and 4 concluding the 25th volume of the Proceedings have been published, and the copy for the papers handed in, for the meetings to date, is in the hands of the printer. During the past year several calls have been made for complete sets of the Proceedings; these we have been unable to supply as three signatures are out of print; two of these have been reprinted and the third is expected this month. The sale of a few sets will exhaust our supply of other signatures, but by thus reprinting a few each year the series can be kept complete for some time.

A memoir, number 10, volume 4, on the Fusion of hands, by Dr. Thomas Dwight has been issued, and 64 pages of Dr. C. S. Minot's Bibliography of vertebrate embryology are in type.

The first part of the new volume of Occasional papers, containing Prof. W. O. Crosby's Geology of the Boston Basin, has been printed and will be issued on the receipt of the two special maps. These are expected this month. The larger part of the expense of publishing this work has been defrayed by Mr. Thomas A. Watson.

The guide to the collections of dynamical geology, a small octavo of 311 pages, also by Professor Crosby, has been issued. This has been paid for outside the resources of the Society.

Twenty-five volumes of vol. 25 of the Proceedings have been bound.

Similar statistics in regard to the publications are given annually, and have been printed in the Proceedings for more than a quarter of a century; it was, therefore, somewhat surprising

to find in the Bulletin of the philosophical society of Washington, vol. 11, p. 221–245 (received last July) a paper by Mr. W. J. McGee, entitled the Evolution of serials published by scientific societies, in which among other errors, the statement is made that only one number of our Memoirs has appeared in the last 17 years, whereas during the 17 years anterior to the date (April 13, 1889) of the reading of Mr. McGee's paper no less than 35 numbers have appeared. It is difficult to account for Mr. McGee's errors; he says that our publications are "fairly accessible"; they are sent regularly to the U. S. Geological Survey, Smithsonian Institution, and elsewhere in Washington. Though I have cited but one of Mr. McGee's errors in regard to the publications of our Society, his paper shows others that a careful writer consulting the official reports of the Society would have avoided. Like many critics, friendly and unfriendly, Mr. McGee does not permit the facts to interfere with his preconceptions.

Walker Prize.

The committee on the annual award of the Walker Prize, announced as the subject, Contributions to our knowledge of the life history of any plant or animal. Their report on the two essays offered in competition will be read later. More interest and competition would probably be secured if the subjects could be announced earlier in the year.

REPORT OF THE TREASURER, EDWARD T. BOUVÉ.

ANNUAL STATEMENT, MAY 1, 1892 TO MAY 1, 1893. BOSTON SOCIETY OF NATURAL HISTORY.

INVESTMENTS.

To cash received Pepperell Mfg. Co. Extra dividend..	$1000.00	By cash paid General Fund, $1000.—C. B. Q. R. R. Bond	$904.17
" " " Miss B. L. Randall. Donation......	5000.00	By cash paid J. W. Randall Fund, $5000.—C. B. Q. R. R. Bond	5181.25
		By cash paid S. P. Pratt Fund Balance invested......	15 92

RECEIPTS AND EXPENDITURES.

Balance from April 30, 1892	$119.58	By cash paid Trustees Walker Prize and Grand Prize Funds	36.54
To cash received from Walker Prize and Special Expense Fund	866.24	By cash paid Special Students' Loan Fund	21.93
To cash received from Walker Grand Prize Fund......	127.17	" " " on account of Repairs	545.23
" " " " Walker Fund Income for General Expenses	1005.00	" " " " " " General Expenses	1080.10
To cash received from Bulfinch Street Estate Fund Income	1632.40	" " " " " " Fuel	213.63
To cash received from Courtis Fund Income	565.76	" " " " " " Gas	60.19
" " " " S. P. Pratt Fund Income	538.88	" " " " " " Insurance	1240.00
" " " " H. F. Wolcott Fund Income	470.65	" " " " " " Publications	605.94
" " " " C. L. Flint Fund Income	294.03	" " " " " " Library	1437.66
" " " " Entomological Fund Income	26.32	" " " " " " Museum and Cabinets	116.66
" " " " J. W. Randall Fund Income	254.20	" " " " " " Salaries and Wages	6210.00
" " " " Admission Fees	138.00		
" " " " Annual Assessments	1233.00		
" " " " Dividends and Income	5770.69		
" " " " N. E. Telephone and Telegraph Co. Damages	750.00		
To cash received on account of Laboratory	2500.00	By cash paid on account of Laboratory: Materials......	20.48
		" " " " " " " Lectures*	1500.00
To cash received from Teachers' School of Science......	2800.00	By cash paid on account of Teachers' School of Science	2881.95
		Balance cash on hand	3020.27
Total,	$25,091.92	Total,	$25,091.92

*A part of the amount paid on account of the Laboratory Lectures is charged to Salaries and Wages.

Mr. N. T. Kidder reported that the Auditing Committee had examined the books and securities in the hands of the Treasurer and had satisfied themselves of the accuracy of the accounts and the safety of the securities.

For the Walker Prize Committee Prof. G. L. Goodale announced that no prize would be awarded this year; the essays offered were not deemed worthy.

It was voted to accept and place on file the several reports.

The Society then proceeded to ballot for officers for 1893–94.

Messrs. R. T. Jackson and L. S. Griswold were appointed a committee to collect and count the votes. They reported twenty ballots cast, all for the candidates nominated.

OFFICERS FOR 1893–94.

The (*) indicates election at this meeting.

PRESIDENT,

*WILLIAM H. NILES.

VICE-PRESIDENTS,

*B. JOY JEFFRIES. *SAMUEL WELLS.
*NATHANIEL S. SHALER.

CURATOR,

*ALPHEUS HYATT.

SECRETARY,

*SAMUEL HENSHAW.

TREASURER,

*EDWARD T. BOUVÉ.

LIBRARIAN,

*SAMUEL HENSHAW.

COUNCILLORS FOR THREE YEARS,

*George H. Barton. *Robert T. Jackson.
*William Brewster. *Nathaniel T. Kidder.
*Miss Cora H. Clarke. *Edward S. Morse.
*William T. Sedgwick.

COUNCILLORS FOR TWO YEARS,

WILLIAM A. JEFFRIES.
AUGUSTUS LOWELL.
Miss SUSANNAH MINNS.
JOHN RITCHIE, JR.
ALFRED P. ROCKWELL.
CHARLES S. SARGENT.
*HENRY F. SEARS.
*THOMAS A. WATSON.

COUNCILLORS FOR ONE YEAR,

S. L. ABBOT.
HENRY P. BOWDITCH.
WILLIAM S. BRYANT.
WILLIAM M. DAVIS.
WILLIAM G. FARLOW.
EDWARD G. GARDINER.
HENRY W. HAYNES.
Mrs. ELLEN H. RICHARDS.

COUNCILLORS *ex-officiis*,

THOMAS T. BOUVÉ.
JOHN CUMMINGS.
GEORGE L. GOODALE.
F. W. PUTNAM.
SAMUEL H. SCUDDER.

Dr. R. T. Jackson described the development of palms.

GENERAL MEETING, MAY 17, 1893.

President W. H. NILES in the chair. One hundred and thirty-nine persons present.

The following paper was read:

THE EDUCATION OF A DEAF BLIND MUTE.

BY CLARENCE J. BLAKE.

[*Abstract.*]

My first knowledge of Willie Robin, two years ago, came through the sound of her voice from an adjoining room. It was the typical voice of an untrained deaf mute, inarticulate, ranging through a short compass of three or four notes into the rising and falling inflection, well marked, and with definite variations in its force value, indicating either a slight remnant of hearing or education of modulation through the tactile sense. The door opened and there entered a child with eager, questioning face, the head thrown back, the sightless eyes upraised, and the arms

stretched outward as if in search of an object with which the restless fingers might come in contact. The movement of the arms was peculiar; the left moved more slowly than the right and was carried across the body; the right swept in an arc from before backward, the fingers of the hand being slightly curved and constantly in motion,—the suggestion being that of the movement of antennae. The moment these questioning fingers came in contact with any substance they immediately began a most minute tactile investigation. If the object were a wall, the fingers were carried up and down it, to the right and to the left, until some break in its surface was found. This might be a crack or a moulding; it might be a horizontal projection or a corner of a bookcase; whatever its direction, or its character, elevation or depression of the smooth surface, it was at once investigated to its ultimate ending. The restless fingers ran over the books in the bookcase, along the backs of the chairs and legs of the tables, down upon the floor and as high upward as the arm could reach. Coming in contact with a person the search became more intimate and the expression of the face more eager and more interested. The corners of the mouth, which were depressed, elevated a little, and while there was no evidence of sight in the eyes or of direct movement of the eyeballs, there was a slight movement of the muscles of the side of the face and of the jaw and above the eyebrows. When the fingers found something entirely new to their cognizance this fact was indicated by a momentary arrest of the process of inspection which was repeated two or three times about the same object.

Comparatively speaking, the face was immobile; the figure, and especially the arms and hands, intensely alert. The child was absolutely blind, totally deaf, and had no other means of communication with the outer world in which she lived than that which came through her sense of touch and its elaborations, her sense of taste and smell. She lived as we might live in interstellar space, in a world absolutely dark, absolutely silent, and, so far as the perception of all the love and the warmth of that affection which has since come into her life, absolutely cold.

She walked somewhat unsteadily and hesitatingly. She doubted approaches which were new to her. She evidently questioned everything that came to her through the limited channel of communication left to her by the disease which had robbed

her in early childhood of two most important senses. Her voice was inarticulate, its cries were modulated, however, and in a limited degree expressive of her meaning. She had but two signs by which she definitely communicated her wants,—the pressing of the closed hand against her lips being a request for food, and of the crossed arms on her breast a demand for water.

The physical state of the case was this: At two years and a half of age the child had cerebro-spinal meningitis with entire loss of the senses of sight and hearing. She was brought up on a Texas ranch, and at six and a half years of age was brought to the Kindergarten for the blind in Jamaica Plain. A careful examination of the eyes and of the ears showed both of these organs to be useless. Her tactile sense was, however, above the normal and her sense of smell exceedingly acute. The disease which had impaired the hearing had apparently also affected the function of the semi-circular canals, as she could be twisted and turned for a long time in any direction without being made dizzy. Her space perception was good, as she measured distances in the movement of her body with great accuracy; her memory in this respect, as in all others where her tactile sense was concerned, being very remarkable and including apparently not only the impressions received through the hands but also through the feet, it being noticeable that she remembered the position of a marble floor, of a wooden floor, of the rising tread of the doorway, or of rugs, whether kept in their place or changed to any position. The power of memorizing, which we who possess all our senses divide in varying proportion among them, this child had concentrated principally upon the remembrance of whatever came within her touch, but it was not until after education for a year or more at the kindergarten when she was taken for a visit to her former home and family in Texas that the extent of her memorizing became fully appreciated. After two years' separation from her family and the opening up to her of an entirely new world she knew her father and her mother the moment she touched them with her hand. Taken to the old house from which the family had removed in the interval of her absence to a larger one, she searched out all the old familiar cracks and crannies; a little hole in the door, the peculiar leather tag by which the door was opened, and a bit of ribbon she herself had tied to the handle,—and it was indeed touching to see her unfasten this and store it

away in her pocket as a memento. She asked for the furniture of which the room had been bereft; found her way directly to the barn near by and to the tree which she used to climb, and even after she had left the place reproduced with her playing blocks upon the floor the house, the barn, the cistern, and the tree, all in the exact relation of direction to each other and in accurate proportion.

Think for a moment of this imprisoned child seeking in darkness and in silence a knowledge of the world about her, and in solitude born of a lack of her own power of communicating, storing up the memories of a home, and self educating that intelligence which later was to blossom out in the warmth and sunshine of a teacher's love-directed work. The character of this work was of necessity based upon the utilization of the tactile sense, and its first step was in the provision of a means of communication between teacher and pupil. This was accomplished through the single hand deaf and dumb alphabet as modified for the instruction of blind deaf mutes, by impressing the letters formed by the hand of the teacher upon the palm of the pupil's hand.

The first experiment in this direction was made in teaching words of one syllable, and was suggested by the child taking a small basket and putting it upon her head as if it were a hat. The word hat was spelled upon the palm of the child's hand, the basket taken from her, again replaced upon her head and the word again spelled in the same manner. The child's fingers were then placed in the position to form the successive letters of the word until coincidentally with the placing of the basket on her head she learned to spell the word herself.

From this first step she has grown in three years to have a vocabulary of over three thousand words, to which she is daily adding, and within two months after her first she had learned not only to understand what was spelled upon her hand but to answer by the single hand alphabet with corresponding rapidity.

With this channel of communication opened, her education went on apace. The next step was to utilize her touch sense for the purpose of making her understand the spoken language. To this end her hand was placed upon the teacher's mouth, throat, and chest, and she was made to appreciate, by having the words spoken spelled out upon her hand, that the movements of the face, the lips, the tongue, the jaw, had a definite meaning and

that they were accompanied by a rhythmic movement which was all that she could appreciate of sound.

By placing the child's lips and mouth in position in imitation of the teacher's movement, and encouraging her to voice herself by allowing her to feel the vibrations of the teacher's voice, she was taught in meager fashion first to speak; and this education has gone on until her vocabulary of *spoken* words is now very nearly two thousand, and she is steadily improving in articulation.

She was also taught to understand, or rather of her own sense speedily acquired power of appreciating, what was said to her when spoken upon her ear, against her face, or upon the back of her hand.

She progressed rapidly in her studies until now at the end of two and a half years she not only can do what has been above mentioned but can read raised type, reciting aloud that which she reads rapidly and with comparative fluency. She is in the Fifth Reader, and has learned to write upon the typewriter.

In analyzing this particular case, one of the first things to be noted is that the child had no *desultory* memory. The impressions which she received instead of coming through several, came through but one channel, and the memorizing capacity was in proportion to the concentration effort in reception. Analysis of the ordinary memorizing faculty for outward things as received through different receptive channels of the senses shows that where the memorizing is accompanied by peripheral exhibition of force, the reflex of that force upon the sensorium emphasizes the memorizing of that which it accompanies. As a rule it is more difficult to remember a given number, one of four figures for instance, if it is heard only. If the number is written upon paper and is seen it is more easily remembered, and still more easily remembered if written by the individual. In the first instance the sense which acts most automatically and with the least conscious effort is the one appealed to, in the second instance the muscular effort accompanying sight serves to make an added impression, while when the figures are individually written there is not only the reflex impression of the tactile sense superficially but of the muscular movement with its co-ordinate impulse in the act of writing and a corresponding movement also of the muscles of the eye in following the contour of the figures, all of which serve to help the memorizing faculty by making a greater

demand upon the nervous force and commensurately giving importance to the consideration of the subject.

In this case also the nervous energy, instead of being expended in an effort at reception through several channels, was limited mainly to one, distinctively volitional, and furthermore instead of being expended in part upon the elaboration of different methods of expression, was devoted almost solely to reception. The intelligence, therefore, which had been slowly educated by an expenditure of effort on the child's own part, reactively was constantly increasing her perceptive power, so that when through the utilization of her quickened tactile sense new forms of expression were afforded her, the concentrated and imprisoned nervous energy burst its bound in a flood of questions which shows no signs of diminution. There is no fairy land imaginable which will compare in its wonders to the new world into which this child has entered within the past three years.

The value of her memorizing faculty from the tactile point of view is still further illustrated in the growth of her speech. It is only necessary to watch her closely during the half-minute in which she will acquire an entirely new word and to hear her reproduce it days afterward, to appreciate the impression which that most delicate of the co-ordinate movements has made upon her memorizing power, and which thus illustrates the statement of Bain, who says (Senses and intellect, p. 339): "When we recall the impression of a word or sentence, if we do not speak it out, we feel the twitter of the organs just about to come to that point. The articulating parts, the larynx, the tongue, the lips, are all sensibly excited. The suppressed articulation is in fact the material of our recollection, the intellectual manifestation, the idea of speech."

In the same manner, the rapidity of her perception of form through the tactile sense is illustrated by her manner of handling objects after the first or second examination. A complicated object, a glass mirror centrally perforated and fitted with a head band for instance, which at the first examination had been carefully investigated in all its parts, was subsequently dismissed with a casual touch which happened to light upon the central opening in the face of the mirror, upon the buckle on the frame of the head band; one of the component parts in the instrument, as appreciated by the touch of a finger, being enough to bring up the image of the whole.

The same efficiency is evidenced in the recognition of an individual. The left hand is moved slowly over the surface of the body, the right hand moving rapidly and with the fingers in more active motion. The investigation includes the arms, the trunk, the neck, and usually finally the face, the peculiarity of costume being apparently sufficiently memorized so that a change in the attire of a person previously seen is noticed and remarked upon. The hands are examined especially upon the palm, and a single sweeping touch is given to a ring or bracelet. In the latter case if there is any special ornament like a pendant, it is held with the fingers of the left hand, and minutely examined with the forefinger and thumb of the right. There is very evident appreciation of difference in texture, but power to appreciate differences in color by the sense of touch has not yet been investigated, though Laura Bridgman has been said to remark of a red cloth that it felt good and warm. It is still a question also in the case of Willie Robin how far the sense of smell may serve to help her in recognizing places and individuals. Apparently she does exercise this sense in reference to individuals, as do some deaf mutes, some blind people, and others fully possessed of all their senses, in whom the sense of smell is said to be especially acute; she has distinguished the vegetables carried through the room on a tray, and has detected by the odor the presence of a dog in an adjoining room. This, however, is evident, that a touch upon the hand, a moving of the fingers over the sleeve or cuffs, or perhaps a momentary search for some identifying object of wearing apparel, a button or a pin, serves to satisfy her in the identification of an acquaintance, and she either pronounces the name or spells it out with her fingers. The degree to which the touch sense and the sense of smell can be educated in connection with her memorizing power would seem to be practically limitless. Experiments with tuning forks in vibration show that like Laura Bridgman she appreciates the rhythmic motion, which is to her the sense of sound, more readily through her fingers than when the butt of the fork is placed in contact with the head, though one of her clinical amusements is to set a fork in vibration by pulling it with her fingers and then to place it on top of her head. A series of experiments with tuning forks showed that when set in vibration and placed upon the forehead Willie Robin distinguished between a low fork of 120 v. s. and a higher fork of 562 v. s., voicing the

former by a deep-toned expiratory sound, and the latter by a shrill cry, though she was manifestly incapable of hearing either; and furthermore the low sound was given with a falling and the high sound with a rising inflection.

General Meeting, November 1, 1893.

President W. H. Niles in the chair. One hundred and fourteen persons present.

The President announced the death of the Rev. Leonard Blomefield, an Honorary Member since August 21, 1839.

It was announced that the following Corporate Members had been elected by the Council: Messrs. Outram Bangs, Henry L. Clapp, George H. Martin, and Townsend W. Thorndike.

Prof. George L. Goodale spoke of the cultivation of tea, coffee, and cocoa.

The following paper was read:—

LIFE HISTORIES OF SOME BOMBYCID MOTHS.

BY HARRISON G. DYAR.

The larval stages of the following bombycids have been hitherto unknown or but imperfectly worked out.

Mr. C. A. Wiley, of Miles City, Montana, has very kindly sent me eggs of the following species, accompanied by the parent moth:—

Eyprepia (Cymbalophora) bolanderi Stretch.

1872—Stretch, Zyg. and Bomb. N. A., 1, 76, pl. 3, f. 13.

1892—Kirby, Cat. Lep. Het., 1, 268.

Egg.—Rounded conoidal, flattened at base, smooth, shining orange-yellow; diameter 0.55 mm., height 0.6 mm. Not attached to any object when deposited by the moth.

First larval stage.—Head bilobed, shining black, labrum pale, mouth brown; width 0.35 mm. Body whitish, the warts, cervical shield, and feet blackish, the warts pearly, each bearing a single long stiff hair. Hair black dorsally, pale laterally. Warts normal in arrangement and size. Length of newly hatched larva about 2 mm. Duration of stage five days.

Second stage.—Head slightly bilobed, rounded, shining blackish; mouth brownish, ocelli black; width 0.5 mm. Body pale brownish, darker sub-

dorsally, thus defining a whitish dorsal line. Warts large, black, with numerous stiff, radiating, rather short hairs. Feet blackish. Duration of stage six days.

Third stage.—As before. A few hairs from the posterior part of the body are long and whitish. Width of head 0.65 mm. Duration of stage seven days.

Fourth stage.—Head entirely shining black with a few hairs; width 0.85 mm. Body blackish, especially subdorsally; warts black, giving the appearance of pale dorsal and subdorsal lines between the warts. Hair short, stiff, black dorsally, whitish subventrally, with three or four long white hairs posteriorly. Duration of stage seven days.

Fifth stage.—Width of head 1.15 mm. Body black subdorsally, pale laterally, all the warts very large, shining black. An orange-red dorsal line ending at anal plate and cervical shield. Hair stiff, short, black, colored as before. Duration of stage seven days.

Sixth stage.—Head black; width 1.6 mm. All deep black except the narrow bright red dorsal line. Sides a little paler; subventral hair pale. Hair thick, bristly, black, covered with little branches or barbs except the few long posterior hairs. The warts of row 2 have shining blue-black bases, the tops punctured and bearing the hairs. Warts of rows 3–5 also elevated, but the bases are fleshy brownish, giving the appearance of obscure pale bands. Tops of all warts deep black. The red dorsal band becomes yellowish white in the segmental incisures, forming conspicuous dots. Later the lateral area appears grayish, against which the black apices of the warts contrast. Hairs from warts 1–3 black; from 4 shading into glassy white; from 5 and 6 pale salmon. Abdominal feet blackish brown, the claspers slightly reddish. Duration of stage seven days.

Seventh stage.—As before. Width of head 2.2 mm. Bases of warts 3 distinctly light reddish, contrasting and forming a broken subdorsal band. Duration of stage eight days.

Eighth stage.—Head shining black; width 2.8 mm. Body black, mottled with whitish (posteriorly on the segments only above the subdorsal band), leaving a black subdorsal band below which the warts of row 3 are distinctly light red, brightest at their bases, only the minute hair-bearing granulations being black. Warts 1 and 2 very black, the rest less reddish than row 3. Dorsal band rather broad, vermilion-red, becoming yellowish white in the incisures; but the color is not seen when the segments are contracted. Hair bristly, cleft into numerous short barbs along its length, black, becoming pale laterally and pinkish red subventrally. Mature larva about 20–25 mm. long. Duration of feeding in this stage seven days.

Cocoon.—A coarse network of silk among leaves or other material on the ground. No hair is used in its construction.

Pupa.—Cylindrical, rounded, abdominal segments tapering. Length 18 mm.; width 5 mm. Color blackish mahogany with a white bloom. Cremaster short and thick, slightly conical, with a terminal tuft of spiny hooks.

Food plants.—Various low herbs.

I owe to the kindness of Miss L. M. Hallowell of West Medford the opportunity to observe the larval stages of the Gypsy moth, the interesting liparid so recently added to our fauna. The larva is closely allied to Notolophus (= Orgyia of Smith's list), possessing the dorsal retractile tubercles on the 6th and 7th abdominal segments, and the enlarged subdorsal warts on the prothoracic segment; but it differs in two important respects from all the known American species of Notolophus and Parorgyia. The first is the absence of the peculiarly branched or plumed hairs which form the defensive "pencils" and "brush-tufts" of our species. All the hairs of *P. dispar* are simple. The second is the presence of an additional series of eversible dorsal glands, not present in Orgyia. These are very small structures, situated in pairs on the first to fourth abdominal segments each side of the dorsal line and anterior to the warts. Porthetria further differs from Notolophus in that the warts of row 4 are well developed instead of being rudimentary; but they have the same location, though their size causes them to become confluent with the warts of row 3. In other respects, as well as in the general system of coloration, the larvae of these genera are alike. The female moths, though winged, seem to fly but little, being, in this respect, intermediate between the almost wingless females of Notolophus and the strongly flying ones of Parorgyia. The species hibernates in the egg state like Notolophus and unlike the species of Parorgyia, which hibernate as half-grown larvae. On the other hand *P. dispar* forms a very weak and frail cocoon, unlike both of the American liparid genera with which I have compared it.

PORTHETRIA DISPAR Linné.

1758—Linné, Syst. nat., 1, 501.

Egg.—Spheroidal; flattened, even concave below when old, smooth, shining orange flesh color. Under a half-inch objective it appears slightly wrinkled and punctured but obscurely so. Diameter 1.1 mm. Laid in a mass or heap, thickly covered with short brown hairs from the body of the ♀ moth.

First larval stage.—Head rounded, shining black; width 0.6 mm. Body brown, densely clothed with short pale hairs. Thoracic feet black. Warts large, bearing many hairs, the subdorsal pair on joint 2 (row 3) especially large and conspicuous with long hairs which overhang the head. Abdominal feet long, with large claspers. The hairs are glassy white, slightly barbed or cleft with pointed ends, and furnished with a

transparent spherule near the base of each. Those from warts 2 are short and even, the lateral ones longer. Later the color becomes brownish with seven red spots on the back, the one on joint 9 paler than the others. There are no retractile tubercles at this stage and the only conspicuous warts are row 2 and the coalesced warts of rows 3–4.

Second stage.— The structure of the mature larva is now assumed. Head shining black; width 1.0 mm. On joints 5–8 a pair of small pale orange retractile tubercles, and a single dorsal one on joints 10 and 11. Body and warts black with traces of a whitish lateral line. Hair thin, some hairs long, others short, black and white mixed. The sides of the body become mottled with yellowish with obscure triple dorsal, single subdorsal and lateral yellowish lines, the subdorsal most distinct.

Third stage.— Head velvety black above, shining black over the clypeus, faintly marked with pale in the median sutures; width 1.8–2.0 mm. Body black, mottled with pale below the subdorsal line and showing besides traces of a yellowish lateral line. A row of dorsal red patches on joints 5–11 connected by a broken red dorsal line which begins on joint 4. On joints 5–9 these patches have a black central dot. Warts of row 2 on joints 2–6 and 12 and row 3 on joint 2 are blue-black; row 2 on joints 7–11 are dark purplish; the rest are pale whitish brown. Dorsal hairs short and stiff, pale, the lateral ones longer and mixed with very long black ones.

Fourth stage.—Head rounded, large and full, brownish white with black marks; clypeus and labrum white. A broad, rounded, vertical, black stripe on each side of clypeus and small black mottlings over the head, which become confluent below the vertex of each lobe in a rounded patch. Or the head may be largely black. Width 2.6–2.8 mm. Body as before; but finely mottled with yellowish. A dorsal and subdorsal, narrow, continuous, yellowish line. Warts of 2 on joints 2–6 blue-black, 3 on joint 2 whitish, 2 on joints 7–12 pale wine color, the rest yellowish flesh color. Retractile tubercles on joints 5–8 yellowish; on joints 10 and 11 orange. Hair long, thin, brownish and black mixed.

Fifth stage (♂ mature larva).—Head pale yellow, marked with black as before. The dots on the sides of the lobes segregate into three large patches. Width 3.7–4.5 mm. Body black, thickly dotted and mottled with yellow, fading into whitish at the sides. Lateral region frosty white in oblique light. A yellow dorsal line dotted with black and a similar broken subdorsal line. Warts very large, arranged as follows: Row 1 present on joints 5–12, very minute, red, situated in front of the minute retractile tubercles on joints 5–8 (which are flesh color) and some distance in front of the large blood-red retractile tubercles on joints 10 and 11; row 2 large, circular, subdorsal, normal; rows 3 and 4 coalesced, row 3 above the spiracle and 4 behind it, the two forming a guard to the spiracle, 4 paler in color than 3; row 5 large, substigmatal; row 6 small, subventral. Row 2 on joint 2 (bisected cervical shield) and on joints 3–6, dark blue; on joints 7–13 blood-red. The other warts are dull pinkish. Dorsal hair bristly, short; lateral hair very long, tapering,

simple. The hair is thin, nowhere concealing the body, black and brown mixed.

Sixth stage.—Female larvae undergo this additional stage with no change in markings. Width of head 6.5 mm.

Cocoon.—Composed of a few threads drawing together loose material.

Pupa.—Slightly flattened ventrally, tapering posteriorly, cases prominent. Tufts of soft spreading brown hairs represent the larval warts and also occur on the slight leg prominences. Cremaster flattened, with two bunches of short hooks. Color brownish black, cases faintly creased, not shiny. Length 15–25 mm.; width 5–10 mm.

I consider the genus Macrurocampa to be well defined; the accessory cell is absent in all the specimens accessible to me. In this respect, it approaches Cerura, which also lacks the accessory cell, except in occasional specimens of *C. occidentalis*.

MACRUROCAMPA MARTHESIA Cramer.

1779—Cram., Pap. exot., 3, 264.

1884—Packard, Amer. nat., 18, 1045.

1893—Dyar, Ent. news, 4, 34.

tessella Packard.

1864—Pack., Proc. ent. soc. Phil., 3, 370.

1867—Grote, Trans. Amer. ent. soc., 1, 182.

turbida Walker.

1865—Walk., Cat. Brit. mus., 32, 407.

Egg.—Flattened, hemispherical, quite flat on the base, the shell thin and translucent, covered with shallow hexagonal depressions of uniform size (seen under a ⅛-inch objective). Diameter 1.3 mm. Deposited singly on the under side of a leaf. The larva hatches by eating a large hole near the vertex.

First larval stage.—Head cordate, higher than wide, flat in front; smooth, shining, pale brownish yellow, with a brown line on each side from the jaw to vertex of head, the two united at the top; width 0.7 mm. Body cylindrical, annulated, shining; on the vertex of joint 2 (first thoracic segment) a pair of divergent fleshy processes, each tipped with a hair and about 0.4 mm. long, colored black at tip and red at base. Anal feet prolonged into a pair of tails five millimeters long, setose, pale brown at base, the outer half black with a broad white ring. Body pale greenish, a subobsolete brown dorsal band, emphasized on joints 5, 7, and 11. A very obscure yellow subdorsal band.

Second stage.—Head conoidal in outline, higher than wide, rounded, not depressed at vertex, flat in front; pale yellowish green, mouth parts brownish, ocelli black; width 1.1 mm. Body as before, the marks rather more pronounced. Cervical horns shorter, pale at base, red at tip, smooth, conical. Tails 5.5 mm. long, pale, with a broad, deep red-brown ring and tipped with same color; extensile threads deep crimson. As the

stage advances, the dorsal band becomes continuous, red-brown, widened into a diamond-shaped patch on joint 7 and a slighter one on joint 5, faintly bordered with yellow; there is a broad yellow band on the head, running from the ocelli straight to vertex of the lobe, uniform in width. The cervical horns become entirely brown.

Third stage.—Head rounded triangular, flat in front; pale green with a broad yellow band on the angle between front and side, running to vertex; ocelli black; width 1.8 mm. Horns short, close together, pointed; tails 6 mm. long. As the stage advances the band on the head becomes red-brown on the anterior side nearly to the vertex; the dorsal band is distinctly bordered with yellow and there is a series of oblique lateral yellow lines, ten in number, each extending over two segments and running together above to form an obscure yellow subdorsal line which lies close to the yellow border of the dorsal band. Feet and venter whitish. Tails uniform pale pinkish, the threads deep crimson.

Fourth stage.—Head rounded triangular, flat in front, higher than wide; pale green, not shining; a vertical band on each side from behind the black ocelli, meeting at the top. The band is yellow, bordered in front with red-brown, mottled, its front edge angulated inward at about the middle; jaws blackish; width 2.7 mm. Two conical, dark red tubercles on the anterior edge of joint 2, close together, each tipped with a hair. Stemapods 5.5 mm. long, pale whitish with a brown line on the inner side. Body marked as at end of last stage, except that the red-brown center of the dorsal band is more reduced and colored darker brown on joints 5, 7, and 11; the oblique lateral lines are not confluent above and the sides are heavily black speckled. Later the dorsal band becomes dotted with white, the two posterior oblique lines become obsolete, represented only by the absence of the black speckles, and the one preceding them on joints 10 and 11 is continued backward as a yellowish substigmatal line to joint 13. The oblique line on joints 4 and 5 is more distinct than the others. The band on the head becomes largely red-brown, mottled with yellow, but still with a yellow border posteriorly.

Fifth stage.—Head oval, much higher than wide, rounded, full, not bilobed; pale leaf-green, smooth, shining, under a lens faintly reticulated. A broad band, with a blunt tooth on its inner side, reaches from ocelli to vertex; red-brown, mottled with pale brown and bordered with yellow on the posterior side. The head is held with the vertex forward, so that this band is parallel with the lateral oblique lines on the body. Mouth whitish, the jaws tipped with black; width 4.3 mm. Body higher than wide, somewhat triangular in shape and tapering from the head to joint 13, which is small. Stemapods absent, their abbreviated bases rounded and held close together, about 1 mm. long. Cervical horns absent, represented by two brown dots close together, each bearing a fine hair. Body pale leaf-green, thickly covered with little purplish black speckles which segregate into short crinkled or circular lines as seen under a lens. They are absent on the sides in 10 oblique bands, which each extend over three segments, from the dorsal line to subventral region. Some of

them are marked faintly with yellow, the one which crosses the spiracle on joint 5 distinctly so. A yellow substigmatal line on joints 11–13. Dorsal band widened on joint 2 anteriorly, also triangularly on joint 7. It is red-brown, mottled with whitish, and bordered with yellow, marked in darker shades on joints 2, 5, 7, and 11.

Cocoon.—Composed of silk, thin, parchment-like, formed among loose material at the surface of the ground.

Food plant.—Oak (Quercus).

Larva from Dutchess Co., New York.

The larva of *Cerura scolopendrina* has not been described, but I believe that I have observed it. No moths were bred from the larvae here described; but several considerations render it probable that they are *C. scolopendrina*, so that I venture to present my notes under the name.

(1) *C. scolopendrina* is common throughout California and was taken by me in Yosemite.

(2) These larvae have not been described before, and could only be *C. paradoxa*[1] of the known Californian forms.

(3) I am informed by Dr. Thaxter, who has bred it, that the larva of *C. aquilonaris* (= *scolopendrina*) is much like that of *C. cinerea*, and those here described recall *cinerea* in the undulating outline of the dorsal patch.

(4) Dr. Behr writes in answer to an inquiry: "[In the larva of] *Cerura scolopendrina* the dorsal band . . . is three times widened, or I would call it twice constricted, but the degree of the constriction is rather variable, so that sometimes, although rarely, the band is almost interrupted."

Cerura scolopendrina Boisduval.
1870—Boisd., Ann. soc. ent. Belg., 12, 186.
1891—Dyar, Can. ent., 23, 87.
1891—Smith, List Lep., no. 1345.
1891—Dyar, Can. ent., 23, 186.
1892—Dyar, Psyche, 6, 290.
1892—Kirby, Cat. Lep. Het., 1, 588.
aquilonaris Lintner.
1878—Lintn., 30th rept. N. Y. state mus., 197.
1882—Grote, Check list, p. 20, no. 272.
1891—Dyar, Can. ent., 23, 186 *pr. syn.*
1891—Smith, List Lep., no. 1339.

[1] There is good reason to believe that *C. paradoxa* is only a very pale form of *C. cinerea*, the larva of which is well known.

1892—Dyar, Psyche, 6, 290 *pr. syn.*

1892—Kirby, Cat. Lep. Het., 1, 588.

‖ *bicuspis* Butler.

1881—Butl., Ann. and mag. nat. hist., ser. 6, 8, 317.

1891—Dyar, Can. ent., 23, 87.

1891—Smith, List Lep., no. 1340, *an sp. americ.?*

1892—Dyar, Psyche, 6, 290, note *pr. syn.*

var. ALBICOMA Strecker.

1885—Streck., Proc. acad. nat. sci. Phil., 1884, p. 284.

1891—Smith, List Lep., no. 1341.

1892—Dyar, Psyche, 6, 291.

1892—Kirby, Cat. Lep. Het. 1, 588.

Egg.—Slightly more than hemispherical, the base flattened, smooth, sublustrous black, under a lens appearing minutely punctured. Diameter 1 mm. Under a half-inch objective it is seen to be covered with flat, irregularly hexagonal and elongated reticulations which become very small at the micropyle. Between them the surface seems smooth with a few extremely minute punctures.

First larval stage.—Head round, slightly shining, dark red-brown, almost black; clypeus and mouth parts paler, ocelli black; a few short hairs; width 0.5 mm. Body smooth, of even width; a pair of spinose subdorsal processes on joint 2; the anal feet modified into spinose stemapods, 3 mm. long; cervical shield small, very dark. Color of body blackish red-brown, feet and venter whitish; two greenish dorsal patches, one on joints 3–5, the other on joints 8–10, elliptical, diffuse at their ends; a third patch appears later, on joint 12. On the body are a number of minute setae. Tails twice annulated with yellowish and tipped with white. Extensile threads black, whitish at the base.

The larvae eat only the parenchyma of the leaf during this stage.

Second stage.—Head rounded, slightly narrowing to the vertex, its sutures deep; color, even red-brown, with a few minute yellow dots; width 0.8 mm. Joint 2 is swollen, its subdorsal processes conical, thick, spinose; low, rounded, small, setiferous tubercles on the body, apparently normal in arrangement; anal plate and stemapods spinose. Body rusty brown with two elliptical, diffuse, dorsal patches of yellowish green, the anterior one on joints 2–6, the posterior on joints 8–10; subventral region and all the feet pale whitish. Tails red-brown at basal half, then blackish, with two sordid white annulations. Length 3.8 mm. As the stage advances the anterior patch becomes larger, joins the subventral coloration, and is obscurely divided by a brown dorsal line, while the whole dorsal region, except joint 11, becomes pale.

Third stage.—Head higher than wide, roundly rectangular, flattened in front; reddish brown, the upper two thirds thickly covered with little round yellowish spots, but leaving a narrow line of the ground color on each side of the central suture above the clypeus; antennae white; width 1.15 mm. Body enlarged at joint 2, bearing a pair of heavily spined subdorsal processes; tails minutely spined. The normal pilliferous dots on

the body consist of conical tubercles, each with a short spine, tubercles one and two on joints 6 and 7 larger than the others. Cervical shield colored like the head; horns red-brown, their tubercles paler; body green, a broad red-brown dorsal band, very narrow and nearly obsolete on joints 3 and 4, widening into an elliptical patch on joints 5–11 and enclosing on joints 7 (posteriorly), 8, 9, and 10 (anteriorly) a patch of the ground color, faintly bisected by a brown dorsal line. On joints 12 and 13 the band is faint, only tinging these segments. Tails red-brown, twice annulated with green; length 4.5 mm. Five days after the molt, the following description was made: Body highest at joint 3 posteriorly; a red-brown dorsal band begins widely on joint 2, covering the horns, narrows to a line on joint 4, rapidly widens and reaches the spiracle on joint 8; then narrows to a line on joint 12 and, widening again, covers the anal plate. It is edged with yellow and contains, on joints 6–9, an ocherous yellow patch which is broken by a narrow, brown, dorsal line and the brown tubercles. The sides of the body are clear green, dotted with yellow. The anterior annulation of the tails is yellowish, the posterior one yellow. Venter, especially posteriorly, whitish. Joint 2 edged with yellow at the sides anteriorly.

Fourth stage.—Head partly retracted beneath joint 2, shaped as before and colored much the same, but yellow on the sides posteriorly; mouth parts whitish; a few piliferous tubercles; width 1.9 mm. Prothoracic horns thick, pointing forward, covered with piliferous tubercles. The tubercles on the body are short, but bear stiff black setae. They are concolorous with the markings except tubercles one and two on joints 6, 7, 10, and 11 which are larger than the rest and blackish. Tails covered with spines which arise from enlarged bases. Body marked as in the last part of the previous stage except that the paler patch on joints 6–9 is more brownish, and the anal plate is tinged with yellowish. Tails 5 mm. long, the extensile threads black, but white at base and middle.

Two days after the molt the markings had more the appearance of the last stage, the central patch (that part of the band on joints 4–11) being slightly indented along its edges in each segmental incisure.

Fifth stage.—Head partly retracted below joint 2, rounded, higher than wide; clypeus small, depressed; red-brown, the upper two thirds, except the clypeus, covered with little, round, yellowish dots, but leaving an obscure line of the ground color on each side of the median suture; yellow at the sides posteriorly; mouth parts pale, jaws brown, antennae yellowish; width 3 mm. Cervical shield large, horns short, rounded, smooth, without tubercles but sparsely punctured. Piliferous dots absent, the setae short and fine. Tails spinose, turned up at the end. Body pale yellow, thickly sprinkled with little whitish and brownish dots, not very distinct; spiracles pale brown; a subventral row of brown spots corresponding to legs on the posterior apodal segments, and a medio-ventral line posteriorly. Dorsal band ferruginous brown, consisting of three connected patches; the first triangular, covering the horns, marked like the head on joint 2 and narrowing to a line at the elevation

spiracle on joint 8, and narrows to a line on joint 11 posteriorly, being incised on its edges in the segmental sutures, shaded with blackish brown around its borders, and containing a darker dorsal and oblique subdorsal line, beside brown dots representing the tubercles; the third, on joint 12 posteriorly and joint 13, elliptical, covering the anal plate, but largely replaced by whitish. All the patches are bordered by a continuous yellow line. Tails brown, green below at base and twice annulated with yellowish green: length 6 mm.

As the stage advances a purplish tint suffuses the dorsal patches, the second one becomes darker obscuring its markings, but three pale orange patches appear in it on each side, behind the former oblique subdorsal lines, distinct or confluent and becoming pinkish yellow. There is a narrow reddish edging inside the now obscure yellow border.

Cocoon.—Made, as usual in the genus, of pieces of bark and wood spun together over the hollow in the wood from which they were bitten out by the larva. The cocoon is not so thick as that of *Cerura multiscripta*, and it can be indented by the finger. It fits the pupa closely.

Pupa.—Cylindrical, slightly flattened ventrally, the ends rounded; no cremaster. Color shining blackish brown, the cases darker, almost black, wrinkled, and less shining than the abdomen. Length 14 mm.; width 4.5 mm.

Food plant.—Willow (Salix). Larvae from Yosemite, California.

If the larvae here described are not different from those of *Cerura bicuspis* Borkh. (which I cannot determine at present), then the name *scolopendrina* must be referred to the synonymy; for all the characters of the European species are exhibited in a series of specimens before me which were collected in California, Oregon, and Colorado. I am satisfied that *C. albicoma* Strecker is only a varietal form, the transverse band of the fore wings tending to be narrower.

LOPHODONTA ANGULOSA Smith and Abbot.

1797—Smith and Abbot, Lep. Ga., 2, 183, Phalaena.

1864—Packard, Proc. ent. soc. Phil., 3, 358, Lophodonta.

1892—Kirby, Cat. Lep. Het., 1, 601.

Egg.—Slightly more than hemispherical, the base flat, smooth, white, not shining; diameter 1.1 mm. Under the microscope it appears covered with granulations of uniform size, except just at the micropyle where there is an area of smaller ones. The shell, after the larva has issued, looks like the end of a thimble, it being difficult to distinguish whether the granulations are convex or concave. The larva hatches by eating a hole in the side. Laid singly on the upper side of the leaves of the food plant.

First larval stage.—The newly hatched larva is entirely shining yellow, 3 mm. long. Head cordate, as wide as high, pale brown, slightly shining; eyes black, mouth brown; width 0.6 mm. Body slender, long, smooth with minute black setae arising from inconspicuous black dots. Anal feet extended nearly backward, slender, partly aborted. Color, leaf-green, shining, a yellow shade stigmatally. All the feet black, contrasting.

Second stage.—Head only very slightly depressed on top; rounded, green, not shining; jaws reddish; a black stripe extends from the ocelli up the side of each lobe, running posteriorly, not attaining the vertex and diminishing in width upward; width 1.1 mm. Body smooth with minute dark setae; green; a faint stigmatal yellow line; all the feet except the anal ones are black.

Third stage.—Head flattened before, clypeus small, depressed; median suture deep, but the head not bilobed. Light green, not shining; a mottled brown band from jaw on each side, not attaining the vertex, but narrowing upward, black at its extremities; ocelli black, jaws green, tipped with brown; width 1.8 mm. Body smooth, the setae minute, green with four narrow yellow bands on each side, the lower substigmatal and bordered above narrowly with red-brown. Thoracic feet blackish; abdominal ones black-tipped. The anal feet are not elevated and are used in walking, but they are small and joint 13 is tapering.

Fourth stage.—Head shaped as before, always large for the body, held out nearly flat, recalling the position of the head in Gluphisia. The line on the side is red-brown, bordered on both sides with yellow, and is continuous with the stigmatal line of the body in the normal position. It does not attain the vertex of the head, terminating in a black point at each end. Jaws yellow with two small reddish lines. Later the sides of the clypeus are defined by a pale yellow line and there are two little yellow streaks at the vertex of each lobe continuing the lines on the body. Width 2.6 mm. Body green, including the feet which are only faintly tinged with blackish, the thoracic ones most strongly so. Slender, tapering posteriorly, the last segment small, though the feet are used in walking and are not elevated in the normal position of rest. No cervical shield nor anal plate distinguishable. There is a broad, double, dorsal, and single, waved, subdorsal, whitish line; a lateral row of yellowish dots, obsoletely connected into a waved line, and a distinct, straight, narrow, stigmatal, yellow line, bordered above with red-brown. Spiracle on joint 2 large, black-ringed, the others reddish. The larva eats away the substance of the leaf from a midrib or vein which it leaves and rests upon with the head generally turned towards the base of the leaf.

Fifth stage.—Head full, rounded, a little higher than wide, flattened in front, the sutures not deep; smooth, shining green, under the lens minutely granular; jaws yellow, with a broad central reddish band, and tipped with black; antennae white, the last joint reddish; a red-brown at joint 3 posteriorly; the second widens rapidly, reaching below the

band over the ocelli, running posteriorly to about the middle of the side of the head, in line with the stigmatal band of the body, bordered on both sides narrowly with yellow; ocelli black; labrum pale, a whitish line on each side of the clypeal sutures, and a faint double mark at the vertex, continuing the double dorsal line of the body. Width 4.2 mm. Body cylindrical, smooth, tapering posteriorly; joint 13 small, the last feet no larger than the others. Setae not distinguishable. Dorsum leaf-green, with a suffusion of white, a distinct white geminate dorsal line; a very faint, narrow, waved and broken subdorsal one; a lateral row of yellowish dots, obsolete at the extremities, three on each segment, the central one higher than the others; a distinct yellow stigmatal line bordered above narrowly and irregularly with red-brown. Spiracle on joint 2 large, white, black-ringed, the others whitish and brown-ringed. Subventral space clear green, unspotted. Thoracic feet pale testaceous with a few black dots outwardly.

The larva seems a close ally of Nadata, but differs in habit; for it rests on the edge of the leaf instead of the back as Nadata does. In its normal position, the clear green of the subventral space joins nicely with the green of the leaf, and the distinct stigmatal line seems to represent an edge or rib of the leaf.

Cocoon.—Found beneath the surface of the earth; composed of silk mixed with grains of dirt; elliptical, thin, complete; size 25 x 12 mm.

Pupa.—Cylindrical, rounded at both ends, thickest through the fourth abdominal segment; anal end almost flat; no cremaster, but a low rounded prominence. Cases creased; abdomen sparsely punctured; color dark mahogany brown, shining. Length 21 mm.; width 7 mm.

Food plant.—Oak (Quercus).

Larvae from Clinton County, New York.

Mr. C. A. Wiley has very kindly sent me the eggs of the following species from Miles City, Montana.

SAMIA GLOVERI Strecker.

1872—Strecker, Lep. Rhop. and Het., 1, pl. 1.

Egg.—Elliptical, slightly flattened above and below. Length 2.2 mm., width 1.8 mm., thickness 1.6 mm. Smooth, white, not shining, with irregular blotches of a brown substance over the surface. The larva hatches by a hole in one end.

First stage.— Head rounded, about as high as wide, median suture deep at vertex, but very shallow in front. Color shining black, labrum paler. A few short pale hairs ; width 1.0 mm. Feet normal, the anal pair very large, the anal plate armed. The armature consists of a series of thick stiff processes, shining black, slightly swollen at tip and bearing a bunch of spreading pale hairs, nearly twice as long as the stem. They are of about equal length, slightly longer on the thoracic segments, and arranged in four longitudinal segmentary rows, as in the mature larva. Row 1 is subdorsal on joints 2–11, 12 and 13 posteriorly (*i. e.*, the anal plate or

tenth abdominal segment), single dorsal on joint 12; row 2 lateral on joints 2–12, stigmatal on joint 13; row 3 substigmatal on joints 2–12; row 4 subventral on joints 2–6, smaller than the others. Color entirely black; but, as the stage advances, a large orange patch appears around the base of each process except those on joint 2 and the dorsal one on joint 12. These spots tend to run together, forming incipient bands. Length 5 mm.

Second stage.—Head shining black, labrum whitish; width 1.45 mm. Body orange color, with two transverse black bands on each segment, indented toward the center, corresponding to the bases of the processes. Processes cylindrical, with enlarged conical base, and bearing at the tip six radiating stiff spines and one vertical one with enlarged base. There are two vertical spines on the single dorsal process of joint 12. The spines are as long as the processes, not longer. Thoracic feet, abdominal ones outwardly, and processes with the spines all shining black. Spiracles white with black edge. There is no cervical shield; but an anal plate is present and a plate at base of each anal foot. All the processes are alike, row 3 about two thirds as long as rows 1 and 2, row 4 short, conical, with only the apical spine present.

Third stage.—Head light yellow with a large black patch on each side of the clypeus and one over the ocelli; labrum, antennae, and palpi black; a few pale hairs; width 2.15 mm. Body pale greenish yellow, darker around the bases of the processes. A dorsal row of black dots, two on each segment. A stigmatal row, one on each segment, posterior to the spiracles; a few ventral black spots. Thoracic feet black, abdominal feet yellow; spiracles white with a narrow black edge. Processes of uniform length, thick, blue-black; their spines rather shorter than the stem. The processes of row 1 on joints 3–5 are slightly thicker than the others.

Fourth stage.— Head as before; width 3.4 mm. Body bluish green, the black dots as before, but reduced. Thoracic feet with the basal joint yellow, the terminal joints black. Abdominal feet yellow with blackish claspers. Spines not more than half or two thirds as long as the stem. Processes thick, forming slight enlargements at the bases of the spines, all shining black except row 1 on joints 3–5 and 12, which are spotted with yellow on the shaft. Spiracles as before.

Fifth stage.— Head round, full, median suture well marked; yellowish green, not shining, with a small black spot on ocelli and a narrow streak each side of the clypeus; mouth whitish; base of antennae and labrum pale blue; width 5 mm. Body large, thick, cylindrical, the incisures well marked; slightly enlarged at the thoracic segments and joint 12; a large square cervical shield and three triangular anal plates, yellowish green. Body bluish green with a gray tint with minute black specks, some of which bear setae. Thoracic feet yellowish green with black tips; abdominal ones yellowish green outwardly, bluish at tip with short black hairs. Processes of row 1 on joints 3–12 gamboge yellow shading paler at base; the others bluish white, shading into pale blue at base with a shining

black basal ring. All the terminal spines black as well as the short rudimentary processes of rows 1 and 2 on joint 2 on the anterior edge of the prothoracic shield. The spines are all short (¼ the length of the process or less) and are partly absent. Only the apical one is present on most or traces of a few others. The processes are thick, club-shaped, and directed slightly backward. Rows 1 and 2 on joints 3–5 and 1 on joint 12 are larger and much thicker than the others, possessing the normal spinulation, partly reduced to black spots. It consists of the apical spine and two concentric rows of radiating ones below it. These processes have a very narrow black ring at base. Spiracles elliptical, white, with a black rim.

The cocoon is very similar to that of *S. columbia* in shape and decidedly blackish in coloration.

General Meeting, November 15, 1893.

Prof. J. S. Kingsley in the chair. Fifty-five persons present.

Dr. J. Walter Fewkes described the ceremonials of the Mexican and Pueblo Indians.

General Meeting, December 6, 1893.

President W. H. Niles in the chair. Forty-seven persons present.

The death of Dr. H. A. Hagen was announced.

Mr. R. E. Dodge gave an account of the geographical development of river terraces.

The following paper was read :—

FACETTED PEBBLES ON CAPE COD, MASS.

BY WILLIAM MORRIS DAVIS.

General occurrence of facetted pebbles on the Cape.—Highland Light, North Truro, South Yarmouth, Succonnessett Point.—The gravel beds of the Cape were subaerial deposits.—Relation of facetting to rock structure.—Postglacial changes of level on the Cape.—Evidence afforded by submerged tree stumps, not trustworthy.

The occurrence of facetted pebbles in our gravels was first brought to my attention by Mr. J. B. Woodworth, whose general account of their distribution is published in the American journal

of science for January 1894, together with a full list of writings upon this subject. The following observations were prompted by Mr. Woodworth's suggestions.

Stratified sands and gravels cover the greater part of Cape Cod. For the most part, they were deposited as a frontal wash from the ice sheet along whose border the morainic hills were built, producing what is often called the back-bone of the Cape. A similar distribution of features is seen in Long Island and in the outlying islands of Martha's Vineyard and Nantucket.

The stratified gravels of the Cape frequently contain facetted pebbles, some of which are now in process of carving by wind-blown sand; some of which have been lately carved, but are now protected from further carving by a scanty cover of vegetation; some of which were carved at the time when the stratum of which they are members was the uppermost of the then accumulated gravel beds, later covered by similar deposits.

Pebbles now in process of carving may be found in great abundance in a gravel bed at the face of the cliff at Highland Light, near the northeastern end of the Cape. They are seen at the head of one of the ravines or gulfs in the cliff face, just north of the Signal Station, and full in the sweep of the strong winds of that exposed situation. They may be gathered in all stages of carving. Some are slightly carved; some strongly facetted on the upper surface as they still lie on the wasting gravel bed; some are distinctly facetted on two sides; that is, they indicate wind carving for a time with one side up, followed by similar action after the pebble had rolled over so as to turn the other side up. When only one side is facetted, the pebble is either still in place, more or less exposed by the removal of the surrounding sand, or else it lies loose on the surface. The varying stages of advance in the carving seems to be a natural result of the retreat of the cliff face under the attack of the waves, the wind, and the weather. The retreat is a steady one, and must cause the removal of the lighthouse before many decades elapse. The pebbles found here show all the variety of facetting, as dependent on rock texture, that will be referred to later on.

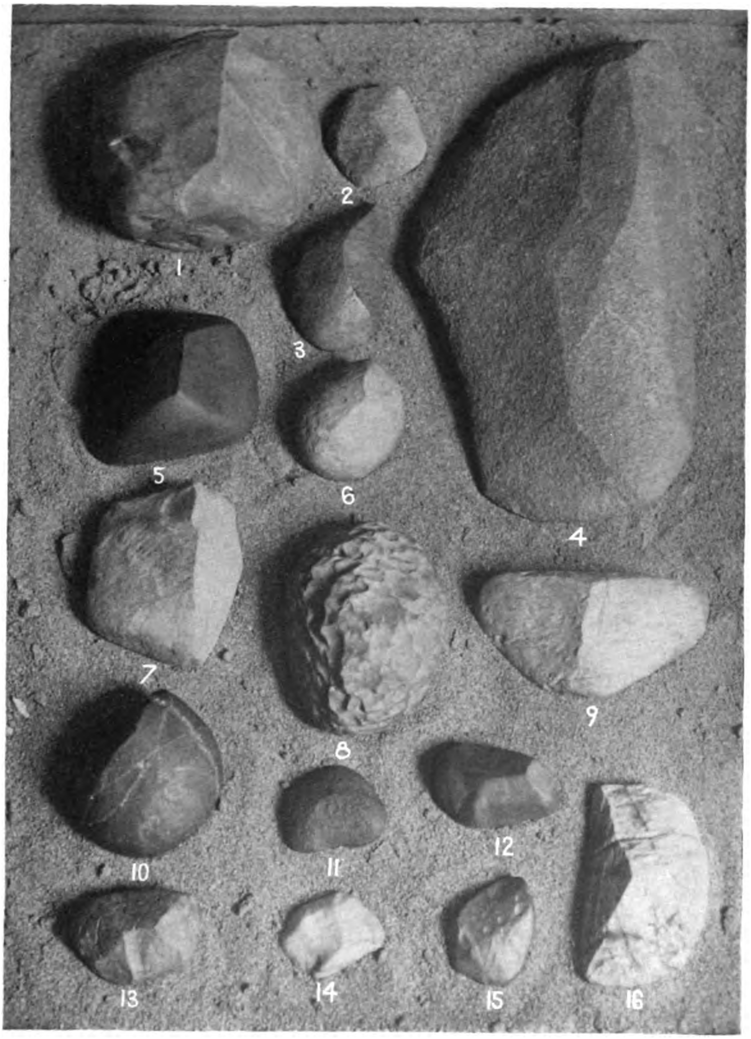
Pebbles recently facetted but now untouched by wind action may be found near the surface of the ground in many railroad cuts; probably in nearly all the cuts on the Cape, judging from the ease with which they were found in the several that I

examined. In some cases, they are so numerous and so large that they may be seen in the gravel banks from the passing trains; it being understood that the trains on the Cape do not travel at lightning speed. The cut at North Truro station may be especially mentioned, as it is here that the traveller leaves the railroad on the way to Highland Light. At the base of the cut, few facetted pebbles were found, and these had probably rolled down from the top, where they were common. At the surface, the gravel beds were thinly and unevenly covered with blown sand. It was manifest that no conditions different from the present, except the absence of vegetation, were necessary to account for the facetting at this point.

The south and east shore of the Cape is frequently cut by the waves, forming a low sea cliff. It is such a cliff that rises along the eastern side or "back" of the Cape, to heights as great as one or two hundred feet, as at Highland Light. At that point, pebbles were found at various depths below the surface, but none were facetted. At South Yarmouth, on the southern shore, where I had much more deliberate opportunity of examining the shore cliff, which there measures at most only ten or fifteen feet in height, facetted pebbles were common down to depths of two or three feet below the original surface. Allowance is made in this measure for the frequent covering of dune sands, which often rise ten or more feet above the marginal surface of the gravel plain; the contact of the two being easily recognized by the soil belt. During the past summer, I have repeatedly examined this cliff at different points, always succeeding after a brief search in finding facetted pebbles in place; and in all cases they lay with the cut edges uppermost. They are also found in the pebbly belt along the water's edge at low tide, where they have been presumably carried from the cliff by the waves.

The highest cliff of stratified sands and gravels on the southern shore is at Succonnessett Point, between Falmouth and Cotuit. The bluff here rises twenty or thirty feet above sea level. The occasional pebbles scattered through the greater part of this section were not facetted; but in the upper eight or ten feet, where pebbles were common, many carved pebbles were found, and, as before, they lay with the facetted side uppermost. The greatest depth at which a pebble with distinct facets was found was about nine feet beneath the surface. Many carved pebbles

DAVIS, FACETTED PEBBLES.



DAVIS, FACETTED PEBBLES.

were found along the base of the cliff; sometimes apparently in place, but then held in large masses of gravel which had slipped down from the top of the cliff.

If it be postulated that these buried facetted pebbles have been carved by wind-blown sand, as they certainly seem to be, then it must be concluded that at least those beds of stratified sands and gravels which contain facetted pebbles were deposited by sub-aerial processes, and not by marine processes below sea level.

First, as to the postulate that the pebbles are wind-carved. Leaving the general discussion of this subject to the paper by Mr. Woodworth, above mentioned, I may briefly consider the alternative explanations; namely, the production of facets by splitting on joint faces; and by action under water, instead of under air.

Professor Shaler describes and illustrates the facetted pebbles of Nantucket under the name of "split pebbles," in his paper on the Geology of that island (Bull. 53, U. S geol. surv., 1889, 23–26, and plate 10). He compares them to the chipped stones found by Dr. Abbott in the Trenton gravels, but shows that while they in a measure resemble artificially-cut stones, yet they must be regarded as natural products. He does not consider their production by wind action, but ascribes them to splitting on joint faces during a recession of the ice sheet by which they were brought part way on their journey from their source; after which they were again carried forward during a later advance of the ice. They are described as being "found in relatively great abundance in all the pebble-drift sections at Nantucket. At Sankaty Head they occur at a depth of 25 feet or so at the crest of the cliff, in positions which seem to indicate that they could not have slipped down from the surface." Although regarded as having been deposited with the rest of the sands and gravels of the beds in which they occur, the attitude of the facetted face of the pebbles in the gravel beds is not specified.

While recognizing this process as a natural one and of presumably frequent occurrence, it does not seem to have been effective in producing facetted pebbles of the kind here described, for these forms are not known in unaltered glacial till. It cannot have been the process by which the characteristic facetted stones of Cape Cod were produced, as it certainly was not by this process that they were so carefully laid, edges up, in the beds of gravel and sand. The edged stones are not weathered or

decayed. They are as a rule normally rounded on one side, as if by water action, and more or less perfectly facetted on the other side. They do not necessarily exhibit any systematic association of internal joints or cleavage with the facets of the surface. Moreover, in the case of most of the pebbles, where two or more facets have been formed, they have a distinct relation to one another, being on one side of the pebble, and all slanting towards a common apex. They are almost as systematically associated as the roof slopes of a house. If a pebble is carved on two sides, the facets as manifestly belong to two systems, instead of to only one.

As to the production of facetted pebbles under water, it would certainly be surprising if after all that has been seen and said about water action, it would be possible for any of its processes to produce edged stones, as sharply cut as those in the gravel beds of Cape Cod. Yet it may possibly be worth while to look into this matter; for if pebbles lie on a shoal, across which the tide carries sand grains back and forth, may not some kind of facetting be the result? If the stone rolls about, it will certainly be rounded; but if it lies still, while the sand passes across it one way and another, it is conceivable that some facetting might result. It is, however, extremely unlikely that this process has been effective enough to produce facetted pebbles in such quantity as they occur on the Cape and elsewhere.

Neither the splitting by weather and glacial action, nor the facetting by water action would account for the known distribution of facetted pebbles. Their common occurrence on the barren surface of deserts, as described by Walther, and their prevailing absence from the till of the later glacial sheets point to their origin under wind action.

Granting this conclusion, it follows that the gravel beds of the Cape were accumulated as subaerial deposits; for it is not to be conceived that any process of transportation could fail to round off the edges of the pebbles in bringing them, already facetted, from some other locality than where they now lie; or that any process of deposition could lay them systematically, edges up, as they are so uniformly found. This peculiar point regarding their occurrence does not seem to have been noted elsewhere in New England, but there can be no doubt of its prevalence on the Cape. There can consequently be no question that the facets

were produced after the pebbles gained their present position; and to my mind, there is practically no question that they were facetted by wind-blown sand.

The advance of facet-carving is very different in different specimens, varying presumably with time and intensity of action and with structure of the pebble acted on. Some pebbles are faintly carved, the amount of material removed being slight and the facets being very small. When the facets are distinct they meet along a more or less sharp and straight line. Some pebbles have three facets, rather symmetrically disposed around a central apex. Others again have four facets, arranged in two pairs of nearly opposed surfaces. It is then generally the case that the faces of one pair are larger than those of the other; the larger surfaces meeting in a main ridge line, while the smaller surfaces cut off the ends of this ridge. It may be supposed that the ultimate form of a fixed pebble, buried to a certain depth in fine gravel, would be a plane surface, even with the surrounding ground; but such "baselevelling" has not been observed. The action does not seem to be persistent enough in one position of the pebble to produce such a result. Instead of this, the long-continued action of the wind seems to result in an undermining of the pebble, by removal of the adjacent sand and gravel; then the pebble falls over, generally exposing another side to the blast, and thus allowing the development of another system of facets. Some of the pebbles from Highland Light, where compound facetting was common, seem to have lost at least a fifth of their original volume by repeated facetting.

Rock texture exerts a marked control of the form produced by the natural sand blast. The finest carving is found in the finer grained quartzites. The two most symmetrical specimens that I have seen, one found by Mr. Woodworth on Martha's Vineyard, the other in my collection from South Yarmouth, are fine brown quartzites; both having two unequal pairs of facets, smoothly and sharply cut. Translucent vein quartz is not spared, although it is not so well carved as quartzite. Inequalities of texture not perceptible to the eye have been searched out in certain specimens, giving a pitted surface. A fragment of conglomerate, found in the railroad cut at Orleans Station, was etched so as to leave the contained pebbles projecting above the surface between them; yet it was not at all "weathered" in the sense of being

loosened by decomposition. Its surface was firm and clean. Similar irregularity of surface was noted in some nondescript crystalline stones at South Yarmouth, in which the knots of harder minerals maintained a somewhat higher surface than their matrix. Granitic and gneissoid stones are unevenly carved; a greater impression being made on the weaker minerals, thus producing a very characteristic appearance of the surface. A coarse gneiss from Succonnessett has a fluted surface on its facets, with rather sharply-marked edges between the flutings. All kinds of stones, however complex in structure, exhibit a facetting more or less clearly; each facet being minutely carved in a way characteristic of the kind of stone that bears it.

The edges between two facets vary with the perfection of facetting. On the quartzites, the edges of well-cut specimens are straight and sharp. Some specimens have two curved facets, meeting in a convex ridge line; but this is exceptional. The gneisses and granites have irregular edge lines. The repetition of these characteristic features in stones of the same kind is very striking.

The greatest depth now reported at which facetted pebbles have been found in our glacial gravels is twenty-five feet, in the cliff at Sankaty Head at Nantucket, as described by Professor Shaler. This would lend much support to the theory that the sand and gravel plains of the Cape, of Long Island, and of the outlying islands, are to be regarded as confluent fan-deltas built up by streams issuing from the ice sheet, at times when its edge lay along the northern margin of the plains. They are therefore homologous with the "*sandr*" of Greenland, described by Holst, and the gravel-fans of Alaska, described by Russell and others. They were built up in front of the ice margin, assuming such a slope as was determined by the size of the streams and by the quantity and quality of their load. It is quite possible that they were built outward into the sea; but the originally submarine portion of these delta-plains may not now be above sea level. It has not been certainly identified.

The gravel plains of the Cape and of the outlying islands are somewhat dissected by shallow valleys. It has commonly been assumed that the land must have risen from the position in which the plains were formed, in order that the streams could cut these valleys. This, however, does not seem absolutely necessary. It

is quite possible that the plains were built up at a time when the streams were surcharged with glacial waste; and that at a later stage, when the load of the streams had decreased, they cut down valleys in the plains that they had before built up. Their action changed from aggradation to degradation. Cases of this kind are well known now in Alaska. Whether this change of activity was sufficient in quantity, as well as in kind, cannot now be determined. But the change should be considered, and until shown to be insufficient, a change in the level of the land does not seem to be essential in explaining the excavation of the valleys.

In view of the evidence of wind action during the growth of the gravel plains, we need not postulate a depression of the land during their accumulation, as might at first sight be thought necessary on account of their distinct stratification, which is so commonly associated with subaqueous processes. In view of the possible change from the aggrading to the degrading action of streams, it does not seem necessary to call upon an elevation of the land after the plains were formed, in order to explain the excavation of the valleys below their general surface. Indeed, the only change of level absolutely demanded in the region of the Cape since the ice lay along its backbone is a slight depression by which the lower parts of its valleys have been drowned into bays. This conclusion would accord well with the results obtained elsewhere by De Geer and Upham.

In this connection, I wish to put on record certain notes regarding the position of tree stumps below salt-water level, outside of the present shore line of Cape Cod. Such stumps may be frequently seen at low tide along the shore at various places; and the fishermen of the Cape know of many tree stumps in deeper water. It was from one of these self-trained observers that I first heard of the following explanation of their origin, independent of changes of level of the land with respect to the sea. Imagine a pond or swamp, a little distance inland from the shore line. In the course of time, as the basin is silted up, vegetation of different kinds will occupy the depression, finally including certain species of trees. While this change is going on, the sea may be pushing back the shore cliff and approaching the old pond. Many an example may be found now in which swampy basins, overgrown with trees, stand practically at tide level,

directly behind a low belt of sands or gravels, which separates them from the consuming waves. In a longer time, or at places of more energetic action, the sand barrier may be destroyed, and then the waves will carry beach sand and pebbles over the soil of the swamp; the trees will die, but their stumps may remain in the muddy soil outside of the beach for a considerable time later.

Many examples of this relation of old swamps and modern beaches may be found. The diverging roots of a dozen or more trees may be counted in the old swamp soil now exposed below the beach sand and gravel at low tide just west of Bass River, a mile from the village of South Yarmouth. The swamp soil is continuous with a marshy belt inland from the sandy beach. The beach has manifestly been pushed inland across the swamp. The occurrence of the tree roots below high-tide level in such a case certainly gives no indication of change of level. If older trees had sunk in the swamp and been buried in its accumulating peaty soil, they might now be found several feet below low water mark. West of Succonnessett Point, a similar relation of existing swamp and old swamp soil with standing tree stumps was noticed, the two being separated by a sand beach, which was manifestly working its way inland, as appears from the receding cliffs directly east of the point.

In mentioning this matter, I do not wish to imply that tree stumps are never carried below ocean level by submergence of the land on which they grew; but merely to point out that the fisherman's explanation as well as the one more generally current among geologists should be considered when such stumps are observed. The case is analogous to that of the rough chipped stones, in which geologists and archaeologists are now so much interested. The newer interpretation of these stones does not prove that no chipped stones are implements; but merely requires that an observation which formerly had but one interpretation must now be considered in the light of two possible interpretations. Whichever one best suits all the facts may then be accepted.

It seems to follow from these notes that the only change of level in southeastern Massachusetts, since the last ice invasion, was a slight depression. As elevation certainly occurred farther north, the depression on the southern coast may have been part of a tilting movement, by which slopes to the south were slightly

increased. The occurrence of submerged tree stumps about the Cape and the islands accords with this explanation, but does not demand it.

EXPLANATION OF PLATES.

Plate 1.

1.	Hornblendic granitite.	Succonnessett.
2.	Quartz porphyry.	South Yarmouth.
3.	" "	Succonnessett.
4.	Granitite.	South Yarmouth.
5.	Quartzite.	" "
6.	Gneissoid granite.	" "
7.	Fine sandstone.	" "
8.	Quartzite.	" "
9.	"	Highland Light.
10.	Red sandstone.	" "
11.	Compact sandstone.	North Truro.
12.	" "	" "
13.	Fine grained sandstone.	" "
14.	" " "	" "
15.	Quartz porphyry.	Succonnessett.
16.	Banded argillite.	North Truro.

All the above are from Cape Cod, Mass., and were collected by W. M. Davis. Scale ½ of natural size.

Plate 2.

1.	Cambrian quartzite.	N. Tisbury, Martha's Vineyard.
2.	Granitite (waterworn).	Succonnessett.
3.	Granitoid rock.	Matakeset Creek, Martha's Vineyard.
4.	Diorite.	Squibnocket.
5.	Quartzite.	Chilmark, Martha's Vineyard.
6.	"	Highland Light, Cape Cod.
7.	Fine grained trap?	South Yarmouth.
8.	Fine grained rock.	Highland Light.
9.	Augen-gneiss.	Matakeset Creek, Martha's Vineyard.
10.	Quartzite.	N. Tisbury, Martha's Vineyard.
11.	Red felsite.	South Yarmouth.
12.	Quartzite.	Highland Light.
13.	Trap.	Cambridge.
14.	Quartz.	Martha's Vineyard.
15.	Quartz porphyry.	" "
16.	" "	Matakeset Creek, Martha's Vineyard.

All the above are from eastern and southeastern Massachusetts. Those numbered 1, 3–5, 9, 10, 13–16 were collected by J. B. Woodworth; 2, 6–8, 11, 12 by W. M. Davis. Scale ½ of natural size.

General Meeting, December 20, 1893.

President W. H. Niles in the chair. Twenty-eight persons present.

It was announced that the following Corporate Members had been elected by the Council: Miss Anne M. Smith, and Messrs. F. C. Kenyon and A. L. Rotch.

Mr. Severance Burrage gave an account of his observations on the thread-leaved sundew, *Drosera filiformis* Raf.

Mr. M. L. Fernald discussed the geographical distribution of the flowering plants of the upper St. John river, northern Maine.

General Meeting, January 3, 1894.

President W. H. Niles in the chair. Thirty-four persons present.

Mr. L. S. Griswold remarked upon the physical geography of Arkansas.

Prof. W. O. Crosby described the gypsum quarries of the lower Carboniferous, Nova Scotia.

General Meeting, January 17, 1894.

Vice-President N. S. Shaler in the chair. Forty-six persons present.

Mr. T. A. Jaggar, Jr., explained the formation of the various kinds of ripple-mark.

Prof. N. S. Shaler spoke of the topographic evidence of ancient earthquakes.

General Meeting, February 7, 1894.

President W. H. Niles in the chair. Two hundred and forty-seven persons present.

The following papers were read:—

ON A COLLECTION OF SMALL MAMMALS FROM THE NEW HAMPSHIRE MOUNTAINS.

BY GERRIT S. MILLER, JR.

During the early part of July, 1893, Mr. Outram Bangs and the writer spent a little less than two weeks in collecting small mammals among the White Mountains. Wet weather during most of this time made trapping so difficult that only a small number of specimens were secured, but many of these are of great interest. Our work was confined to two localities, the summit of Mount Washington, and the region between Profile Lake and Franconia. The greater part of the time (July 8–17) was spent on Mount Washington, where our work was confined to the treeless summit. At Franconia and Profile Lake we worked but three days, July 18–20 inclusive.

Mount Washington is in the southern part of Coös County, New Hampshire, and rises to a height of 6,280 feet. It is the principal peak of the Presidential Range, the highest mountains in New England. Dense forests of spruce, balsam, and paper birch cover the sides of these mountains up to about 4,000 feet, at which altitude the trees become dwarfed. All tree growth disappears at slightly above 5,000 feet, giving place to a vegetation of hardy alpine herbs and shrubs. The summit of Mt. Washington is everywhere covered with loose fragments of rock, and presents a barren and forbidding appearance. Our trapping here was done chiefly in three places: (1) at the head of Great Gulf (5,500 ft.); (2) in the Alpine Garden near the head of Tuckerman's Ravine (5,400 ft. to 5,200 ft.); and (3) at the Lake of the Clouds (5,200 ft.). There was little variation in the general character of the land. Everywhere the loose fragments of rock were more or less covered with turf of hardy sedge. Beneath the rocks and turf, cavities abounded, in which running water might often be heard. Surface water occurred frequently in depressions or extensive level areas. In the Alpine Garden there were numerous ice-cold pools and rills, the latter appearing suddenly, and, after wandering for a few rods among the rocks, as unexpectedly vanishing. Near the Lake of the Clouds there were several good-sized ponds, the exact size of

which I found it impossible to estimate. Naturally the vegetation was more profuse in wet places, and hence we found there a greater abundance of animal life.

The flora of the mountain top is of such interest in connection with the other life of the region that I give here a list of the plants that we observed above 5,000 feet.[1]

Isoetes lacustris
Lycopodium annotinum pungens
" selago
Aspidium sp.
Poa laxa
Trisetum subspicatum molle
Calamagrostis langsdorffi
Phleum alpinum
Hierochloe alpina
Carex atrata ovata
" rigida bigelovii
" canescens alpicola
Eriophoron vaginatum
Scirpus caespitosus
Luzula spicata
" spadicea melanocarpa
Veratrum viride
Clintonia borealis
Streptopus roseus
" amplexifolius
Maianthemum canadense
Habenaria dilatata
Picea nigra (dwarf)
Abies balsamea (dwarf)
Empetrum nigrum
Salix herbacea
" uva-ursi
" phylicifolia
" argyrocarpa
Betula glandulosa
" papyrifera minor
Polygonum viviparum
Rhinanthus crista-galli
Euphrasia officinalis tatarica
Castilleia pallida septentrionalis
Veronica alpina
Trientalis americana
Diapensia lapponica
Loiseleuria procumbens
Ledum latifolium
Rhododendron lapponicum
Kalmia glauca
Bryanthus taxifolius
Cassiope hypnoides
Chiogenes serpyllifolia
Vaccinium vitis-idaea
" caespitosum
" uliginosum
" pennsylvanicum angustifolium
Prenanthes boottii
" serpentaria nana
Arnica chamissonis
Solidago macrophylla
" virgaurea alpina
Houstonia caerulea[2]
Lonicera caerulea
Linnaea borealis
Viburnum pauciflorum
Cornus canadensis
Heracleum lanatum
Epilobium hornemanni
" angustifolium
Ribes lacustre
Amelanchier oligocarpa
Pyrus americana
Potentilla frigida
" tridentata
Fragaria virginiana
Geum radiatum peckii

[1] For aid in determining many of these plants I am indebted to Mr. Edwin Faxon, whom we had the good fortune to meet at the Summit House.

[2] A very large, pale form, apparently distinct from the lowland plant.

Rubus triflorus	Silene acaulis
Spiraea salicifolia	Viola blanda
Oxalis acetosella	" palustris
Claytonia caroliniana	" canina muhlenbergii
Stellaria borealis	Coptis trifolia
Arenaria groenlandica	Thalictrum polygamum

The characteristic and abundant plants of the region are chiefly such arctic-alpine species as *Carex rigida bigelovii*, *Geum radiatum peckii*, *Arenaria groenlandica*, *Diapensia lapponica*, *Castilleia pallida septentrionalis*, and various heaths and willows. Some typical Canadian forms are common and generally distributed, while a few plants having a still more extended range to the southward occur in profusion. Among the former may be mentioned *Cornus canadensis*, *Ledum latifolium*, and *Clintonia borealis*, while in the latter category belong *Veratrum viride*, *Trientalis americana*, and *Viola blanda*. The most noticeable grass-like plant found about the summit is *Carex rigida bigelovii*. This forms dense masses of turf wherever a gully or depression among the rocks allows soil to collect, and must be of the utmost importance to the mammals of the region, forming as it does their chief source of food and shelter.

On comparing the elements of the flora and mammal fauna of the summit of Mt. Washington we see certain very marked differences. There is but one peculiar alpine mammal (*Evotomys gapperi ochraceus*), the other species being such as occur also at the base of the mountain. On the other hand at least one half of the plants are arctic-alpine forms, either restricted to this and neighboring mountain tops or found also in the high north.

Of bird life about the summit there is little to say. The only species found breeding above 5,000 feet was *Junco hiemalis*. This bird was common in various parts of the Alpine Garden (5,300 feet) and among the scrub spruces near the Lake of the Clouds (5,200 feet). It was also seen flying about among the rocks near the Summit House on the extreme top of the mountain. The young were well on the wing at the time of our visit, and many were caught in Schuyler traps set for red-backed mice in the spruce scrub. *Zonotrichia albicollis* breeds well up toward the head of Tuckerman's Ravine where its song was often heard as we were at work in the Alpine Garden a thousand feet above. I doubt whether the bird's range extends beyond 5,000 feet, though

once or twice individuals were seen in the Alpine Garden. These when disturbed instantly plunged down into the Ravine. A thrush was seen among the scrub spruces in the Alpine Garden one very foggy morning, but it was impossible to identify the bird, which soon disappeared over the edge of the Ravine. One robin flew wildly past me near the head of Great Gulf (5,500 feet) on the morning of July 19. We saw no other birds on the Summit.

Profile Lake is situated in Franconia Notch, the altitude of which is about 2,000 feet. It lies in the midst of a dense forest of spruces, pines, and birches. The lake has its outlet toward the south through the brook which afterwards becomes the Pemigewasset River. For the first hundred yards this stream is rather sluggish, with low swampy banks and muddy or sandy bottom. Its character soon changes, however, and it becomes a typical mountain brook, tumbling over a bed filled with rocks. Franconia is four miles north of Profile Lake. Its altitude is about 1,000 feet. The country between these points is in part densely wooded and partly open. The flora of the region is, like the avi-fauna,[1] predominantly Canadian. On account of the shortness of our stay in this region the list of mammals is necessarily very incomplete. Through the kindness of the Franconia natural history society, I have at hand the small mammals belonging to the excellent local collection of the Society. Acknowledgment of these will be made in due order.

The late Mr. Frank Bolles also furnished some interesting notes on the mammals found near Chocorua, Carroll Co., N. H.

List of Mammals.

1. Sorex personatus Dobson.

Two adults of this small shrew were secured in the Alpine Garden, Mount Washington.

There is a mounted specimen in the collection of the Franconia natural history society.

2. Sorex platyrhinus Dobson.

We did not meet with this shrew, but I have seen a specimen taken by Mr. Frank Bolles at Chocorua, N. H.

[1] See Faxon and Allen, Auk, v. 5, p. 149–155, April, 1888, for lists of the summer [birds] of the region.

3. Sorex albibarbis (Cope).

Our chief object in visiting Profile Lake was to secure topotypes[1] of the *Neosorex albibarbis* Cope. The two original specimens of this species were taken on the shore of Profile Lake in September, 1859, the original description appearing three years later in the Proc. acad. nat. sci. Phil., 1862, p. 188. Since then the history of the species has been uneventful. So far as I know, up to the present year but one additional specimen has been taken. This individual, from Warwick, Mass., was recorded by A. E. Verrill in the Proc. Bost. soc. nat. hist., v. 9, p. 164, October, 1862, under the name of *Neosorex palustris;* Mr. Verrill proving to his satisfaction the identity of the animal with Richardson's *Sorex palustris.* Mr. J. A. Allen mentions this specimen under the same name in his Catalogue of the mammals of Massachusetts (Bull. mus. comp. zool., v. 1, p. 211, 1869). I can find no additional references to Neosorex from the eastern states until April, 1892, when Dr. C. Hart Merriam enumerates both *S. palustris* and *S. albibarbis* among the mammals of the boreal zone (Proc. biolog. soc. Wash., v. 7, p. 25).

We captured two specimens within a few hundred yards of Profile Lake; and I also have a series of seven examples from Elizabethtown, Essex Co., N. Y., taken in May and June, 1893. The specimens from these localities are certainly identical, and that they represent a species distinct from *Sorex palustris* I think there can be no doubt.

Richardson, in the original description of *Sorex palustris*, states that the dorsal aspect of his animal is black with a slight hoary appearance when turned to the light. This applies very well to the present species. Continuing his description Richardson says: "On the ventral aspect it is ash-colored." This statement can scarcely apply to the eastern specimens. These are rather dark smoke-gray on the belly fading to nearly white on the chin and throat. The term ash-colored was applied in the second volume of the Fauna Boreali-Americana to much paler tints than this. Thus, the ventral surfaces of such birds as *Spizella monticola* and

[1] The term "topo-type," recently proposed by Mr. Oldfield Thomas (Proc. zool. soc. Lond., March 14, 1893, p. 242) for specimens "collected at the exact locality where the original type was obtained," is much more satisfactory than the term "duplicate type" used in the same sense by Dr. Merriam (N. A. fauna, 1, p. 4, foot-note.) Topo-type has the advantages of brevity and exact connotation, while the term "duplicate type" is self-contradictory, since type specimens must necessarily be unique.

Lanius borealis ♀ are called respectively "ash-colored" and "ash-gray." Since we know that these descriptions were for the most part drawn up by Richardson (see Swainson, On the nat. hist. and classif. of birds, v. 1, p. 218, 1836), it is safe to assume that the terms were used in a like manner in the first volume of the same work. Now, the belly of either of the birds just mentioned is very many shades lighter than the corresponding surface of *Sorex albibarbis*. Moreover the plate of "Ash-Grey," no. 9, in "Werner's Nomenclature by Syme," the standard used in the second volume of the Fauna Boreali-Americana, indicates a color quite unlike that of the belly of *Sorex albibarbis*. In Richardson's statements concerning the size of his *Sorex palustris* we find nothing satisfactory, since the measurements were taken from a prepared specimen. The hind foot is given as 9 lines (= 19 mm.). This is within the limits of *S. albibarbis*. The other characters mentioned by Richardson are so general as to be of no use in the present connection. This animal is said to occur in marshy places from Hudson Bay to the Rocky Mountains. Turning now to other evidence we find that both Audubon and Dobson have published figures of the type specimen of *Sorex palustris*, the former representing the external appearance of the animal, the latter the teeth. Audubon's plate shows a distinctly bicolored shrew, the belly being almost white, in striking contrast with the black back, thus very different in appearance from *S. albibarbis*. On the other hand, Dobson's figure of the teeth (Monogr. Insect., part 3, fasc. 1, pl. 23, fig. 18) agrees in most respects with the specimens from New Hampshire and New York.

On the Pacific coast, in the Rocky Mountains, and in northern Minnesota occur marsh shrews whose color differs strikingly from that of specimens from the eastern states. These shrews (whether there is more than one species I am not prepared to say) are strongly bicolored, with nearly black backs, and bellies almost white. Two specimens from Elk River, Minnesota, are, through the kindness of Dr. C. Hart Merriam, now before me. As these agree perfectly with Richardson's description of *Sorex palustris* and with Audubon's plate of the type specimen of that species, and, moreover, as Elk River is very nearly within the limits of the range of *S. palustris* as given in the original diagnosis, I have little hesitation in referring them to Richardson's

species. It is possible then to define the two animals as follows:

SOREX PALUSTRIS Richardson.

Sorex palustris Richardson, Zool. journal, v. 3, p. 517, 1837. Fauna Bor.-Am., v. 1, p. 5, 1829. Audubon and Bachman, Quad. N. Am., v. 3, p. 108, pl. 125, 1853. Dobson, Monogr. Insect., part 3, fasc. 1, pl. 23, fig. 18.

? ? *Neosorex navigator* Baird, Mam. N. Am., p. 11, 1858 (Coast of Washington).

? *Sorex palustris* Merriam, N. A. fauna, no. 5, p. 35, July 30, 1891 (Idaho).

Adult male (No. $\frac{2505}{3015}$ collection of Dr. C. Hart Merriam, Elk River, Minn., January 30, 1886, Vernon Bailey collector): dorsal surface very dark seal-brown with a slight greenish gloss, each hair with a narrow subterminal band of smoke-gray separating the seal-brown tip from the slate-gray under fur, and producing a slight grizzled appearance when the animal is viewed in certain lights; ventral surface very pale smoke-gray, nearly white, and faintly tinged with cream color; the color of the belly extending a short distance on the sides where it shades quickly into the color of the back; inner surfaces of all four legs colored like the belly; dorsum of manus and pes sepia, paler on the inner half; tail clear seal-brown dorsally and at tip, pale smoke-gray ventrally, this gray area broad proximally but soon narrowing to a mere line, persisting, however, to the extreme tip.

The other adult male from the same locality (No. $\frac{2506}{3016}$ collection of Dr. C. Hart Merriam, February 20, 1886) is similar to the one just described, but has the ventral surface much more strongly tinged with cream color.

SOREX ALBIBARBIS (Cope).

Neosorex albibarbis Cope, Proc. acad. nat. sci. Phil., 1862, p. 188.

Neosorex palustris Verrill, Proc. Bost. soc. nat. hist., v. 9, p. 164, October, 1862. Allen, Bull. mus. comp. zool., v. 1, p. 211, 1869.

Sorex albibarbis Merriam, Proc. biolog. soc. Wash., v. 7, p. 25, April 13, 1892.

Adult male (skin and skull, No. 2483 collection of Gerrit S. Miller, Jr., Profile Lake, New Hampshire, July 20, 1893): dorsal surface very dark seal-brown, almost black, with faint greenish reflections, the hairs marked subterminally with smoke-gray, thus producing a slight grizzled appearance; fur everywhere slate-gray at base; ventral surface sepia a

little mixed with smoke-gray, becoming clear smoke-gray on chin and fading insensibly into the color of the back; dorsum of manus and pes sepia, paler on the inner side, the former also paler distally; tail clove-brown dorsally, grayish ventrally.

A somewhat younger topo-type (♀ alcoholic, No. 2484 collection of Gerrit S. Miller, Jr., same date), in rather better coat than the one just described, has the back similarly colored, but is slightly paler in the middle of the belly and on the chin, which parts are strongly tinged with smoke-gray, contrasting lightly with a darker shade between the front legs.

These two specimens resemble precisely in color those taken at Elizabethtown, N. Y., except that the male is somewhat darker and more uniformly colored on the belly than any of the latter. In fact it would be hard to find nine animals more precisely alike in color than these.

MEASUREMENTS OF *Sorex albibarbis* (COPE).

No.	Locality.	Date.	Sex.	Total length.	Tail vertebrae.	Hind foot.	Height of ear.	Ratio of tail vertebrae to total length.
2483	Profile Lake, N. H.	July 20, '93	♂	157	68	19	9	43.3
2484	" " "	" 20, "	♀	149	65	19.6	7	43.6
2428	Elizabethtown, N. Y.	May 27, "	♂	155	73	19.4	9	47.1
2429	" "	" 27, "	♂	151	70	18.8	8.6	45.7
2430	" "	" 27, "	♂	152	71	19	8	46.7
2431	" "	" 29. "	♂	150	68	19	8.4	45.3
2432	" "	June 12, "	♀	158	76	20	8.8	48.1
2433	" "	" 4, "	♂	162	73	20	8.4	45.0
2434	" "	" 6, "	♂	155	68	19	9	43.2

In color this species differs so strikingly from *S. palustris* that a detailed comparison of the two is hardly necessary. *Sorex palustris* is of a uniform shade throughout the ventral surface, while in *S. albibarbis* the chin is noticeably paler than the surrounding parts, a feature which suggested to Professor Cope the very appropriate specific name. In *S. palustris* the pale ventral stripe on the tail persists to the extreme tip, while in *S. albibar-*

bis it is much less extensive. The fringes on both front and hind feet are noticeably darker in *S. albibarbis*.[1]

With the small amount of western material at my disposal I cannot find any good cranial or dental characters to separate the two animals, the teeth of both agreeing essentially with Dobson's figure referred to above.

4. Blarina talpoides (Gapper).

Two specimens taken on Mount Washington and a third at Profile Lake. The Mount Washington individuals differ somewhat from true *B. talpoides*, being slightly smaller and with ears smaller than in the latter. They may represent a distinct form, but the material at hand is insufficient to warrant any separation.

Mr. Bolles found this shrew common at Chocorua.

Through Dr. Merriam's kindness I have before me seven specimens of Blarina taken by the field agents of the U. S. department of agriculture at Council Bluffs, Iowa, and at Blair, Nebraska. These may be considered topo-types of Say's *Sorex brevicaudus*, the type of which was collected at Engineer Cantonments, near Council Bluffs. A careful comparison of these specimens with more than one hundred short-tailed shrews from the eastern United States, Nova Scotia, New Brunswick, and Ontario shows that they represent a distinct and easily recognizable form. The name *brevicauda* must be restricted to the western animal, while for the short-tailed shrew of the eastern states and adjoining British Provinces we may use Gapper's name *talpoides*. The type of *Sorex talpoides* Gapper came from the region between Lake Simcoe and the county of York, Ontario, and, although I have seen no specimens that can fairly be regarded as topo-types, a shrew collected by Mr. A. C. Brooks at Mount Forest, Ontario, about sixty miles due west of the region in question, is perfectly typical of the eastern animal. Although Baird more than thirty years ago recognized the distinctness of these two shrews, they have been confused by subsequent writers.

[1] Since writing the above I have examined the entire series of skins of Neosorex — mostly from the Rocky Mountains — in the U. S. national museum. Many of these specimens were taken in midsummer and yet all are sharply bicolored, none in the least resembling *S. albibarbis*. *Sorex albibarbis* is, however, curiously like *S.* (*Atophyrax*) *bendirei* in color, the chief difference between the two being that the latter is of a uniform shade throughout the ventral surface, with no indication of a whitish chin.

BLARINA BREVICAUDA (Say).

Sorex brevicaudus Say, Long's Exped., 1, p. 164, 1823.

Blarina brevicauda Baird, Mam. N. Am., p. 42, 1857.

Blarina brevicauda Allen, Bull. mus. comp. zool., v. 1, p. 213, 1869, (part).

Sp. Ch. Hind foot averaging about 16 mm.; tail well haired and generally with a conspicuous pencil often 10 mm. in length when unworn; colors always dark and sooty; average length of skull about 23.5 mm., rostral portion broad and heavy.

Adult (♀ No. $\frac{31993}{43784}$ U. S. national museum, Council Bluffs, Iowa, November 14, 1891): color of dorsal aspect intermediate between seal-brown and mouse-gray, almost blackish in some lights, in others with a dull metallic gloss, fading into rather dark smoke-gray on the belly; tail not sharply bicolor, brownish dorsally, paler ventrally; dorsum of manus and pes concolor with belly.

The cranial characters of this species may be more conveniently discussed with those of the next.

BLARINA TALPOIDES (Gapper).

Sorex talpoides Gapper, Zool. journ., v. 5, p. 208, pl. 8, June, 1830.

Blarina talpoides Baird, Mam. N. Am., p. 37, 1857.

Blarina brevicauda Allen, Bull. mus. comp. zool., v. 1, p. 213, 1869, (part).

Sp. Ch. Hind foot averaging about 14.4 mm.; tail scantily haired and with pencil seldom if ever exceeding 6 mm.; color pale, and often silvery; average length of skull about 22.5 mm., rostral portion narrow.

Adult (♀ No. 1148 collection of Gerrit S. Miller, Jr., Elizabethtown, N. Y., January 5, 1892): back rather dark smoke-gray with a strong silvery gloss when held in certain lights, in other lights with a faint yellowish tinge; belly smoke-gray or shining silvery gray according to light; no sharp line of demarkation between colors of back and belly but change taking place rather suddenly on the sides; hairs on dorsal and ventral surfaces of tail concolor with fur of corresponding surfaces of the body; dorsum of manus and pes silvery gray.

The difference in color between these animals is rather hard to describe, but it appeals to the eye at once when series are compared. In general *B. brevicauda* has the duller, darker, more sooty tints, while *B. talpoides* has the colors brighter, paler, and more silvery. In the worn summer pelage, the color differences are slight if any, but in the full autumn and winter coat they are well marked. The hairiness of the tail seems to be a rather variable character, as some individuals of *B. brevicauda* have the

tail nearly as scantily haired as the average *B. talpoides*. The latter species, however, never shows the extreme hairiness of tail often found in *B. brevicauda*.

The skulls of *B. brevicauda* and *B. talpoides* differ in general size and in the proportionate development of the rostrum. Five skulls of *B. brevicauda* average 23.64 mm., in total length (exclusive of incisors), while the average of twenty skulls of *B. talpoides* is but 22.60 mm. In *B. brevicauda* the ratio of greatest ante-orbital width to occipito-rostral length is 38.16, against 33.27 in *B. talpoides*. Although the greater breadth of the rostrum makes the brain case appear proportionally narrower in *B. brevicauda*, the development of this part of the skull in the two species is in reality nearly the same, since the ratio of greatest post-orbital width to occipito-rostral length is 55.83 in *B. brevicauda*, 54.77 in *B. talpoides*.

The teeth of *Blarina brevicauda* are, like the skull, more heavily built than in *B. talpoides*, but I can find no differences in relative size or form.

Concerning the geographic distribution of these two shrews nothing definite can be said. *Blarina brevicauda* ranges from western Iowa and southeastern Nebraska north to central and eastern Minnesota, while *B. talpoides* occurs from near the eastern side of Lake Huron to the Atlantic coast. Whether the two forms will be found to intergrade somewhere in the region of the Great Lakes is entirely problematical. For the present they must stand as distinct species.

5. Scapanus americanus (Bartr.).

A fine specimen of the hairy-tailed mole is in the collection of the Franconia natural history society.

6. Condylura cristata (Linné).

An adult male taken in the Alpine Garden (5,400 feet), Mt. Washington, July 9, 1893, is slightly smaller than the average of twenty specimens from Peterboro, N. Y. Although small in size the animal is fully adult, with claws much worn. The specimen was taken in a "cyclone" trap set in a cavity beneath the turf close to a small stream. No indication of moles' work could be found here or elsewhere on Mount Washington.

Specimens of this species, including a family of half grown young, are in the collection of the Franconia natural history society.

7. Sciurus hudsonius Pall.

Common between Profile Lake and Franconia.

Numerous at Chocorua (Bolles).

8. Sciuropterus volans sabrinus (Shaw).

A flying squirrel in the collection of the Franconia natural history society is referable to the Canadian form. Although it is said to occur somewhat plentifully near Profile Lake, we did not meet with the animal.

9. Tamias striatus lysteri (Rich.).

A partially tamed chipmunk lived in the rocks immediately below the Summit House. It is said that chipmunks, red squirrels, and flying squirrels now and then appear about the buildings on the summit, the two last never remaining for any length of time. We saw one individual of this species near Profile Lake on July 20. Mr. Bolles found it not uncommon at Chocorua.

10. Arctomys monax (Linné).

I shot an adult female woodchuck a few hundred feet from the summit of Mount Washington on July 12, 1893. The animal was running about among the loose rocks near the railroad, and appeared to be ill at ease, as if in strange surroundings. I have no doubt that it had wandered up from the lower country, following the clearing along the line of the railroad. We could find no indication of woodchucks' work anywhere on the summit.

11. Zapus insignis Miller.

Common in the neighborhood of Profile Lake where numerous specimens were taken.

Mr. Bolles reported the animal tolerably common at Chocorua, and Mr. Bangs has taken it at Dublin in the same State.

Since publishing my last account of *Zapus insignis* (Proc. biolog. soc. Wash., v. 8, p. 1–8, April 22, 1893), I have examined nearly one hundred additional specimens. These in every way bear out the characters of this remarkable species.

12. Sitomys americanus (Kerr).

A few occur about the buildings on the summit of Mount Washington where five perfectly typical specimens were taken. There can be little doubt that the species is introduced, doubtless brought up the mountain with the firewood used in the Summit House.

Mr. Bolles found this mouse common at Chocorua in open or scantily wooded places, and near buildings.

13. Sitomys americanus canadensis Miller.

The Canadian white-footed mouse occurs sparingly throughout the region explored on Mount Washington. Several were trapped under one of the barns on the summit, and we secured specimens in Great Gulf, the Alpine Garden, Tuckerman's Ravine, and near the Lake of the Clouds. These specimens are in every way typical of this strongly characterized race or species.

We also took specimens at Profile Lake, and Mr. Bolles has found the animal at Chocorua. In both of these localities the mouse is strictly confined to dense woods.

I have examined several hundred additional specimens of Sitomys of the *americanus* group since describing this form (Proc. biolog. soc. Wash., v. 8, p. 55, June 20, 1893). This material in every way confirms the characters then brought forward, and makes me feel less inclined to treat the animal as a subspecies. Specimens intermediate between *S. americanus* and *S. a. canadensis* are of the utmost rarity, and, as I have already stated, do not occur in any particular region.

A series of over one hundred skins of *Sitomys americanus arcticus* received from Mr. Will C. Colt who took them at Osler, Saskatchewan, differ from *S. americanus canadensis* only in their grayer ears and much shorter, more strongly bicolored tails. In the general color of the body the two forms are exactly alike. The ears of *arcticus* are, however, more hairy than those of *canadensis*, the whole peripheral internal portion being densely covered with short silvery white hairs. Externally the ears are silvery white, except a broad band running from the anterior base almost to the tip. This area is nearly black in strong contrast. This striking color pattern is not constant, but it occurs so frequently as to give a decided character to a large series of specimens. Only the faintest suggestion of such marking is to be seen in the ears of *S. a. canadensis*. In the most extreme examples of *S. americanus arcticus* the tail is very sharply bicolor, pure white ventrally and black dorsally; the black dorsal stripe in strong contrast with the color of the animal's back. In other specimens this stripe shades to dark sepia, about as in the darkest-tailed individuals of *S. americanus canadensis*. Mr. Colt did not measure the total length of his specimens, so no direct compar-

ison in size can be made with *S. americanus canadensis.* As compared with the length of head and body, the tail vertebrae in *S. americanus arcticus* average about 25 mm. less; while in *S. americanus canadensis* the tail vertebrae exceed the length of head and body by about ten millimeters.

14. Arvicola riparius Ord.

An adult male and two nearly full-grown young taken in the Alpine Garden, Mt. Washington, July 9 and 10, 1893. These specimens do not differ appreciably from those taken at lower altitudes in various parts of the eastern United States.

We observed the species at Franconia, and Mr. Bolles reported it common at Chocorua.

15. Arvicola chrotorrhinus[1] sp. nov.

Specific characters: slightly smaller than *Arvicola riparius* Ord, with broader hind feet; in color most like *Arvicola xanthognathus* Leach, but decidedly grayer, and with ochraceous patches on muzzle less strongly marked. General shape of skull much as in *Evotomys gapperi* (Vigors); pattern of enamel folding as in *Arvicola xanthognathus* Leach, but posterior upper molar with three closed or nearly closed outer triangles.

Adult (Type ♀ skin and skull, No. 2522 collection of Gerrit S. Miller, Jr., Mount Washington, N. H., July 14, 1893; taken near the head of Tuckerman's Ravine at about 5,300 ft. altitude): length, 165; tail vertebrae, 45; hind foot, 19.4; ear, 13.8; back and sides brown of a shade intermediate between raw umber and broccoli-brown, the fur everywhere sprinkled with black-tipped hairs, these slightly less numerous on the sides; area from muzzle to and surrounding roots of whiskers tawny ochraceous in strong contrast with the adjacent parts, a faint tinge of the same color suffusing the whole head and sides of the neck; belly silvery gray,[2] the bases of the hairs here as elsewhere blackish slate, the dark color showing through to a slight extent; tail sepia dorsally, hair brown ventrally; dorsum of manus and pes silvery gray; soles thickly clothed from heel to proximal tubercle with fine grayish hairs.

The five adults of *Arvicola chrotorrhinus* show remarkably little individual variation in color. One (♂ No. 2523) is slightly darker than the type, and is faintly tinged with fulvous about the base of the tail. Another (♀ No. 2520) has the toes and the tip of the tail white. The ochraceous nose patches are slightly more marked in some individuals than in others, but are very evident in all

[1] χρῶς, χρωτός, color, ῥίς, ῥινός, nose.

[2] Ridgway, Nomenclature of colors, pl. 2, no. 10.

The young are uniformly grayer than the adults, with nose patches much paler and less clearly defined, involving more or less the whole face, and back of the eyes shading gradually into the color of the body. Three of the four young have the digits of the hind feet white to a greater or less degree, two of them have the tail also tipped with white, while in one of the latter the digits on both of the front feet are white, and there is a narrow band of the same color extending from chin to breast.

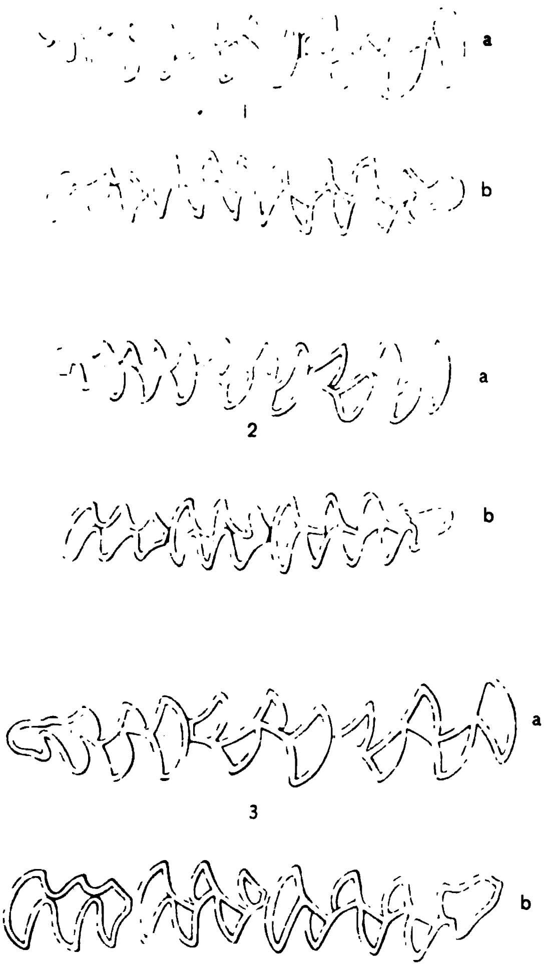
Arvicola chrotorrhinus is so different from any of the known North American species that a detailed comparison with these is scarcely necessary. From *Arvicola xanthognathus* its very much smaller size and grayer color will serve at once to distinguish it. The prevailing tint in *A. xanthognathus* is a pale wood-brown, the belly and feet very strongly suffused with the same color. In *A. xanthognathus* (seventy-three specimens) the hind foot averages 23.75 mm. (see Coues, Monogr. N. Am. Rodentia, p. 201, 202, 1877). In *A. chrotorrhinus* the hind foot averages 19.4 mm. *Arvicola chrotorrhinus* does not in the least resemble *A. riparius* except in size and general tone of coloring, its nose patches, broad hind feet, peculiar skull, and pattern of enamel folding making it a very different animal.

The skull of *Arvicola chrotorrhinus* (pl. 3, figs. 3 and 4) resembles in form no species of Arvicola with which I am acquainted. It suggests rather that of *Evotomys gapperi* (cf. pl. 3, fig. 1). This is due to the great width and distinct concavity of the inter-orbital region, and the breadth and shallowness of the brain case, the latter peculiarity being carried even farther than in *Evotomys gapperi*. Although the resemblance to the skull of Evotomys is very striking in the dorsal and lateral aspects, it ceases entirely when the ventral surface is examined, since the foramen magnum is shaped as in *Arvicola riparius*, while the pàlatal structure and broad strong tooth rows are unmistakably those of an Arvicola. On the other hand the audital bullae are slightly larger proportionally than in *Arvicola riparius* and *A. xanthognathus*, in this respect again approaching Evotomys. All the structural details of the skull are as in Arvicola, the likeness to Evotomys being purely superficial.

In dentition *Arvicola chrotorrhinus* agrees with *A. xanthognathus* in lacking the posterior internal loop of the middle upper molar, but differs from this species and from *A. riparius* in the

presence of three closed or nearly closed outer triangles in the posterior upper molar in addition to the usual terminal crescent (pl. 4, fig. 2a). Otherwise the pattern of enamel folding shows no peculiarities. There are, however, in this respect some interesting variations. In the posterior upper molar the external triangles tend to remain open, communicating more or less broadly with those of the opposite side. This is especially the case with the type, though in no one of the five adults are these triangles so tightly closed as in the average *S. riparius*. The specimen from Profile Lake differs from all the others in lacking the third outer triangle in the posterior upper molar. This I regard as merely an extreme case of individual variation. Two of the adults (Nos. 2523 and 2528) are peculiar in having the anterior loop of the first lower molar deeply cut by an internal re-entrant angle, the apex of which reaches nearly across to the enamel of the opposite side, making the tooth appear to have four internal triangles.

We found this interesting new Arvicola near the summit of Mount Washington and at the outlet of Profile Lake. But one specimen was taken at the latter place, so it is impossible to say whether the animal is of regular occurrence there. On Mount Washington we took eight examples, an adult and four young at the Lake of the Clouds, and three adults near the head of Tuckerman's Ravine. The first specimen was caught near the edge of the Lake of the Clouds on a mound of rock fragments beneath which we could hear running water. The mound was thickly covered with *Carex rigida bigelovii* interspersed with willows (*Salix argyrocarpa*), blueberries (*Vaccinium uliginosum*), raspberries (*Rubus triflorus*), and many herbaceous plants such as *Viola palustris*, *Coptis trifolia*, *Geum radiatum peckii*, *Streptopus roseus*, and the like. Near the lower part of the mound and between this and the lake a sphagnum (*S. girgensohnii stachyodes*) grew in profusion. Although there could be no doubt that numerous mice lived in the mound, all our efforts to trap them failed. A few rods away, however, the four young ones were secured. At the head of Tuckerman's Ravine we again found the animal where a dense turf of Carex covered the bare rocks, leaving a labyrinth of cavities beneath through which water was flowing. These specimens were all taken in traps set under the turf. The mice apparently live wholly in the natural cavities



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MILLER, WHITE MOUNTAIN MAMMALS.

among the rocks, as we could find no indications of the usual Arvicola runways. Bits of sedge, the leaves of Peck's Geum, and green shoots of various kinds were sometimes found drawn into these cavities and partly eaten, but the mice if numerous left remarkably little indication of their presence. The specimen taken at Profile Lake was trapped in a hollow beneath a rock close to the stream less than one hundred yards below the lake. It is of course impossible to say whether the animal is common in this region. Mr. Bolles did not find it at Chocorua, nor have I taken it in the Adirondacks where I have collected in ground very similar to that near Profile Lake.

Since writing the above I have examined an *Arvicola chrotorrhinus* taken at Trouser's Lake, N. B., October 7, 1893, by Mr. C. P. Rowley. This specimen (♀ No. $\frac{6598}{5210}$ American museum of natural history) considerably extends the range of the species. Mr. Rowley says it was trapped in deep mossy spruce woods.

MEASUREMENTS OF *Arvicola chrotorrhinus* MILLER.

No.	Locality.	Date.	Sex.	Total length.	Tail vertebrae.	Hind foot.	Height of ear.	Ratio of tail vertebrae to total length.
2520	Mt. Washington, N. H.	July 12, '93	♀ ad.	163	47	20	13.4	28.8
2521	" " "	" 13, "	♀ ad.	176	49	20	14	27.8
2522	" " "	" 14, "	♀ ad.	165	45	19.4	13.8	27.3
2523	" " "	" 15, "	♂ ad.	175.5	51	19	15.5	29
2524	" " "	" 12, "	♀ juv.	110	31	19	10	28.2
2525	" " "	" 13, "	♂ juv.	111	29	18.4	10.4	26.1
2526	" " "	" 13, "	♀ juv.	110	28	18	10 4	25.4
2527	" " "	" 14, "	♂ juv.	121	31	19	19	25 6
2528	Profile Lake "	" 19, "	♂ ad.	163	48	19	13	29.4

16. EVOTOMYS GAPPERI (Vigors).

We secured an immature red-backed mouse, probably referable to the common Canadian species, at Profile Lake, July 19, 1893.

Mr. Bolles found this mouse in all suitable localities near Chocorua.

17. EVOTOMYS GAPPERI OCHRACEUS subsp. nov.

Subspecific characters: slightly larger than *Evotomys gapperi* (Vigors) with longer, softer fur and colors duller, paler, and more ochraceous.

Adult (Type ♀ skin and skull No. 2533 collection of Gerrit S. Miller, Jr., Mount Washington, N. H., July 12, 1893, collected in the Alpine Garden near the head of Tuckerman's Ravine at about 5,300 feet altitude): length, 148; tail vertebrae, 39.6; hind foot, 19; ear, 13; dorsal surface clay color, shading gradually to reddish mars-brown on rump and lumbar region and to cream-buff on the sides, everywhere inconspicuously varied with blackish and whitish hairs; belly smoke-gray slightly tinged with cream color and mixed with the blackish slate of the basal part of the fur, the color of the ventral surface passing insensibly into that of the sides; dorsum of manus and pes grayish white; tail indistinctly bicolor, sepia dorsally and at tip, cream colored ventrally.

Young (♀ skin and skull No. 2538, same locality as adult, July 14, 1893): dorsally grayish rufous, becoming grayer on the sides and fading into smoke-gray on the ventral surface, where, as in the adult, the dark bases of the hairs show through distinctly.

There is little variation in color among the adults of *Evotomys gapperi ochraceus*. Some are slightly more tinged with red than others, and the amount of the cream colored wash on the belly is variable. One adult male (No. 2542, July 11) is as red as the paler examples of *E. gapperi*, and a few others approach this specimen in richness of tint. The black-tipped hairs on the back and sides are never conspicuous. The young are as uniform in color as the adults. Several of the immature examples show a very distinct wash of cream-buff in the middle of the belly, while one male two thirds grown (No. 2550, July 9, 1893) has a conspicnous buff stripe from nose to shoulder separating the color of the dorsal and ventral surfaces. This individual is also slightly albinistic, being marked with a narrow white line in the middle of the belly.

Evotomys gapperi ochraceus differs strikingly from *E. gapperi* in its strongly ochraceous tints and almost entire lack of red. An adult of the latter form (♂ No. 1570) taken at Peterboro, Madison Co., N. Y., July 17, 1892, is ferruginous dorsally, becoming slightly brighter on the rump and lumbar region and shading gradually to buffy clay color on the sides; the belly cream color. Throughout the back and sides the fur is noticeably sprinkled with black-tipped hairs. The fur in the lumbar region in the type of *E. gapperi ochraceus* is 14 mm. long; in the specimen just described its length is but 10 mm. In each of these specimens the pencil measures 6 mm. The specimen of *Evotomys gapperi* just described very fairly represents the average of a large series of summer examples. The winter

pelage of *E. gapperi* is somewhat paler, but the red is at the same time brighter and clearer than in summer. The differences observable in the adults hold good when young of the two races are compared; immature examples of *E. gapperi* being much the darker and more red.

In its long fur and pale color *Evotomys gapperi ochraceus* shows an approach to the arctic *Evotomys rutilus*. *E. rutilus* is, however, a much redder animal, with more hairy feet and tail. A specimen of this species (No. 5581 Mus. comp. zool.), taken near the Porcupine River, Alaska, by Kennicott, is orange-rufous dorsally, the fur plentifully mixed with black-tipped hairs. The belly is buff (Ridgway, Nomenclature of colors, pl. 5, fig. 16), the sides and face a slightly paler shade of the same color. Dorsum of manus and pes, and ventral surface of tail concolor with belly. Dorsal surface of tail like the back, but rather more mixed with blackish hairs. Pencil, 10 mm.; fur on rump, 17 mm.

Through the kindness of Messrs. S. N. Rhoads and Witmer Stone I have before me the type and several other examples of the *Evotomys gapperi rhoadsii* described by Mr. Stone[1] from May's Landing, N. J. These specimens resemble *Evotomys gapperi ochraceus* in the reduction of the amount of red in the pelage, but instead of being paler and more ochraceous than *E. gapperi* they are distinctly darker and browner.

This mouse needs no comparison with *Evotomys carolinensis* Merriam, which to judge by the description[2] is a larger and darker animal, the back being dull chestnut liberally sprinkled with black-tipped hairs. The hind foot of *E. carolinensis* averages "19.5 mm"; of the *E. gapperi ochraceus* 18.8 mm.

Eight adult Evotomys and a two thirds grown young taken near the summit of Mt. Graylock, Mass. (3,500 feet) early in May, 1893, though not perfectly typical of *E. gapperi ochraceus*, approach this form more closely than they do true *E. gapperi*. From this fact it seems probable that this new red-backed mouse will be found to inhabit the higher mountain tops throughout New England and New York.

The foregoing descriptions and comparisons are based on an examination of twenty-three specimens of *Evotomys gapperi ochra-*

[1] Amer. nat., v. 27, p. 54, Jan. 1893.

[2] Amer. journ. sci., ser. 3, v. 36, p. 460, Dec. 1888.

ceus and nearly three hundred specimens of *E. gapperi* and various allied forms.

This red-backed mouse is the only abundant mammal on the Alpine summit of Mount Washington. We found it in the most varied situations—in the foundations of the buildings on the summit; among loose rock fragments where the only vegetation consisted of lichens and the hardy *Carex rigida bigelovii;* in the thick moss and dwarf willows (*Salix herbacea*) at the head of Great Gulf; throughout the Alpine Garden, and among the scrub spruces near the head of Tuckerman's Ravine; and by the margin of the Lake of the Clouds. Runways which we supposed were made by these animals abounded among the matted herbage just exposed by the melting snow in Tuckerman's Ravine and Oakes's Gulf, though the work may have been in part due to *Arvicola chrotorrhinus.* In fact wherever it was possible for a mouse to live, the red-backs occupied the ground almost to the exclusion of all other species. Under a large flat stone in the Alpine Garden I found a nest filled with last year's berries of *Vaccinium vitis-idaea.* Runways led away in every direction among the sphagnum, sedge, and scrub spruces. This was probably an Evotomys storehouse, for traps set here yielded this species exclusively.

MEASUREMENTS OF *Evotomys gapperi ochraceus* MILLER.

No.	Locality.	Date.	Sex.	Total length.	Tail vertebrae.	Hind foot.	Height of ear.	Ratio of tail vertebrae to total length.
2529	Mt. Washington, N. H.	July 9, '93	♀ ad.	155	41	19	14	26.4
2530	" " "	" 11, "	♀ ad.	157	40	19	14	25.5
2531	" " "	" 11, "	♀ ad.	154	42	19	13.4	27.3
2532	" " "	" 12, "	♀ ad.	171	48	20	15	28
2533	" " "	" 12, "	♀ ad.	148	39.6	19	13	26.8
2534	" " "	" 14, "	♀ ad.	153	41	19	12.4	26.8
2535	" " "	" 16, "	♀ ad.	152	38	19	12	25.1
2541	" " "	" 11, "	♂ ad.	148	40	19.6	13	27.1
2542	" " "	" 11, "	♂ ad.	161	49	19.8	14.6	30.4
2543	" " "	" 11, "	♂ ad.	150	40	19.4	14	26.7
2544	" " "	" 12, "	♂ ad.	155	42	19	12.8	27.1
2545	" " "	" 13, "	♂ ad.	144	39	18.4	12	27.1
2546	" " "	" 13, "	♂ ad.	149	41	18.4	14.2	27.5
2547	" " "	" 15, "	♂ ad.	149	37	20	14.5	24.8
2548	" " "	" 15, "	♂ ad.	146	37	20	14.5	25.3
2549	" " "	" 15, "	♂ ad.	140	35.5	18.5	14.5	25.4

EXPLANATION OF PLATES.

Plate 3.

1. *Evotomys gapperi* (Vig.) ♀ No. 1983. Peterboro, N. Y., Oct. 11, 1893.
2. *Arvicola riparius* Ord. Topo-type. Near Philadelphia, Pa.
3, 4. *Arvicola chrotorrhinus* Miller. Type.
5, 6. *Arvicola xanthognathus* Leach. ♀ No. 2555. Yukon River, Alaska.
(All figures about × $\frac{3}{2}$.)

Plate 4.

1. *Arvicola riparius* Ord. Topo-type.
   a. Left maxillary molar series.
   b. " mandibular " "
2. *Arvicola chrotorrhinus* Miller. Type.
   a. Left maxillary molar series.
   b. " mandibular " "
3. *Arvicola xanthognathus* Leach. No. 2555.
   a. Left maxillary molar series.
   b. " mandibular " "
(All figures about × 10.)

SOME TYPICAL ESKERS OF SOUTHERN NEW ENGLAND.

BY J. B. WOODWORTH.

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CONTENTS.

Introduction.

This paper includes little more than a brief discussion of certain eskers from the point of view of the bearing of their topography and distribution on the question of their genesis. Their structure is mainly neglected for the reason that by far the greater number of eskers remote from the larger towns are not exposed by artificial sections. The few opportunities to examine the arrangement and nature of the detritus of eskers have afforded no facts which have not been previously described and commented upon in the writings of Stone, Upham, and Davis. The observations have been drawn from field work on the following named atlas sheets lying within the three States, Massachusetts, Rhode Island, and Connecticut: Boston, Dedham, Providence, Fall River, Abington, Barre, Brookfield, Blackstone, Webster, Newport, Narragansett Bay, Burrillville, New Haven, Meriden. The investigation is a part of the studies made in mapping the Pleistocene deposits of this district and has been conducted under the immediate charge of Mr. N. S. Shaler.

Terminology.

The term *esker* is employed in this paper to designate those elongate and often serpentine ridges of gravel and sand which mark the course of water-channels in the ice-sheet of the last glacial epoch. The term *kames* is used in the restricted sense proposed by Chamberlin, and is intended to denote collectively the mounds of gravel and sand often bordered by hollows, which sometimes accompany moraine terraces, the heads of sand-plains, and areas of water-laid drift lying within the field occupied by the ice-sheet. *Moraine terrace* is used in the sense advocated

by Gilbert in his monograph on Lake Bonneville. A few other terms are explained in the connection in which they appear.

Bibliographic Résumé.

The following publications relate to the distribution of eskers in this district.

Prof. Edward Hitchcock[1] early recognized the resemblance of the eskers of this district to the osar(s) of Sweden and Russia and to the "escars" or "scoeurs" of Ireland. In various works he published a map of the eskers near the Shawsheen River in Andover.

Gray and Adams[2] give a map of the Andover eskers, and refer them to "oesars."

Prof. G. F. Wright[3] has described and mapped the Andover and other eskers in north-eastern Massachusetts, under the name of kames, and has attempted to show the connection of groups of these deposits in a continuous system. He advocates the superglacial origin of eskers.

Although the Andover eskers have been repeatedly described and mapped, beyond referring them in the later accounts to a superglacial origin the several authors have not brought out other relations which these deposits may have borne to the ice-sheet.

The eskers of Hingham have been pointed out by Prof. W. O. Crosby[4] and Mr. T. T. Bouvé,[5] under the name of kames. They "occur along the side of Weymouth Back River, north of Great Hill, and in the vicinity of Cushing and Accord Ponds." To one of these deposits Professor Crosby ascribes the diversion of Weir River from a preglacial valley into Nantasket Harbor. Mr. Bouvé describes their course, argues for their superglacial origin, and notes the eastward trend of the ice-sheet as indicated by the corresponding direction of one of the group.

[1] Elementary geology.

[2] Elements of geology, New York, 1853, p. 114-115.

[3] Kames and moraines of New England, Proc. Bost. soc. nat. hist., v. 20, p. 210-220.—Bailey, Historical sketches of Andover, Mass., 1880, p. 19-24.

[4] Physical history of the Boston Basin, 1889-90. Second lecture.

[5] Geology of Hingham.

Prof. N. S. Shaler noted the general relations of the eskers of this district in a paper "On the origin of kames,"[1] and later described an esker near Gloucester on Cape Ann,[2] as crossing a valley. He also described as an esker a deposit within the morainal highlands of Martha's Vineyard,[3] but this deposit I am informed by him is to be considered as a drift-covered ridge of tilted sands and gravels involved in the Gay Head uplift.

The late Prof. J. H. Chapin[4] in 1890 examined the low esker southeast of the city of Meriden, Conn., and found it with "the gravel and cobble-stones, some of them bearing glacial striae, lying flat in the ridge and the whole having a rude stratification."

Prof. W. M. Davis[5] has described the structure and geological condition of the esker at Auburndale, Mass., and has demonstrated the subglacial origin of this deposit.

Mr. F. P. Gulliver[6] has published a description and photograph of the eskers associated with sand-plains near Newtonville, Mass.

There are many scores of eskers in this district which as yet have found no mention in the literature and are not represented on maps.

The Slopes of Eskers.

The key to the interpretation of deposits of water-laid drift came with the recognition of the meaning of the steep slopes which mark the moraine terrace, the typical eskers, the heads of glacial sand-plains, the sides of many kettle-holes, glacial ponds, and kames. The disposition of loose material on these slopes at the angle of repose argues in each case the removal of support, and the sole satisfactory explanation postulates the melting of masses of ice against the walls or over the surface of which the

[1] Proc. Bost. soc. nat. hist., v. 23, p. 36–44, 1884. In this paper, Professor Shaler showed the relation of an esker in the Adirondacks with a subglacial stream depositing at its mouth as the ice retreated.

[2] Ninth Annual report U. S. geol. survey, p. 549–550.

[3] Seventh Annual report U. S. geol. survey.

[4] Trans. Meriden scientific assoc., Jan., 1891.

[5] The subglacial origin of certain eskers. Proc. Bost. soc. nat. hist., v. 25, p. 477–499, 1893. Abstract: Jour. geol., Chicago, v. 1, p. 95–96.

[6] Jour. geol., Chicago, v. 1, p. 803–812, 1893.

gravels and sands were originally deposited. This slope may also originate in till accumulated along the ice-front. There are hummocky slopes less than the angle of repose in which the topography is due to the same cause, the difference arising from the mode of deposition upon a gently inclined rather than a steep surface of ice. Some hillside kames belong here. This slope marks the contact of the ice-sheet or its remnants with the detritus deposited about its base. It is then a *contact-line*, and is to the glacial geologist what contacts and unconformities are to the student of the older rocks. The materials on the slope are differentiated from those in the mass through their arrangement by gravity, and by reason of their subsequent deposition on the slope. Professor Chamberlin[1] has proposed a system of mapping topographic forms to show relative chronology. The moraine terrace slope and its homologues in the heads of glacial sand-plains and the slopes of typical eskers may then be colored to show (1) contact between ice and glacial drift, (2) the distribution of gravity slopes (taluses), or (3) contemporaneous glacial terraces.

These slopes are to be distinguished from those formed by the adjustment to gravity of terraces of erosion. Gilbert has given the differentiae in his monograph on Lake Bonneville. The slopes must also be distinguished from those made in glacial deposits by the liquefaction of buried ice and the settling of an overlying cover of drift.

Steep sides are characteristic of typical eskers. Like the slopes of the moraine terrace, they mark the contact with walls of ice once existing on either side of the ridge of gravel. The typical moraine terrace is exterior to the ice-sheet: the esker is interior. Eskers, then, since they extend often nearly unbroken for miles into the interior of a now vanished ice-sheet, must bear in their form and structure indications of the conditions which there prevailed during the period of their formation, and their importance as geological monuments is the greater if we find them to be of the class formed near or at the base of the ice-sheet. The relation of slopes to crest-line elevation will be discussed in the following section.

[1] A proposed system of chronologic cartography on a physiographic basis. Bull. G. S. A., v. 2, p. 541–544, 1891.

The Crest-line of Eskers.

The crest-line of eskers varies in elevation not only with reference to the slope of the terrane on which the deposit rests, but also with reference to the base of the esker itself. Gilbert[1] notes of eskers "that the ridge tends to equality of height rather than to horizontality."

The crest-line is seldom horizontal for more than a few rods; but long, gentle grades of even crest-line occur, having lengths varying from a few rods to nearly half a mile. Such grades are seldom straight lines but are commonly curved. An esker may increase in thickness in this manner from almost nothing to 100 or more feet, gaining correspondingly in breadth of base. The Auburndale, Mass., esker illustrates this class of changes.

Contrasted with the gently sloping crest-line are the segments of an esker having short, steep grades, with materials at the angle of repose. Where these slopes recur at short intervals, a kame-like surface is assumed, and not infrequently the esker widens out into a small kame-field. Examples of this class obtain in segments of most long eskers.

According to one view, the hummocky outline of an esker reflects the elevations of depressions in the arch of the subglacial stream in which it is supposed the esker was deposited. By another conception, the same outline is supposed to be due to irregularities induced by the gradual lowering of the bed of a superglacial stream to the base of the ice. This last view permits several variations, and like the preceding ascribes the variations of the crest-line to vertical changes in the configuration, or rate of melting, of the ice-sheet. The ice-tunnel and ice-cañon have been supposed to operate to the same end. Still another view explains the rise and fall of the esker crest as the effect of violent currents in sweeping away detritus in constricted passages and laying it down where the velocity of transportation was diminished by the enlargement of the water way.

There is yet another way in which the elevation of the crest-line of an esker may be changed, and a simple experiment with blocks of ice so placed as to bound a channel of varying width may readily be conducted to demonstrate the principle I shall

[1] *Op. cit.*, p. 87.

now set forth. If in a channel at the base of a stagnant and disappearing glacier, detritus be laid down with a constructional surface relatively even, but with a width varying within short distances, so that at one point the width is less than the thickness, and at another point greater than the thickness of the deposit, the ultimate crest-line of the deposit, when the ice melts away, will vary. The caving of the sides will produce slopes whose intersection will take place above the constructional surface where the deposit is wider than it is high in the ratio of one to one and one half (about). Where this ratio or a greater one obtains, the constructional surface along its median line will not be lowered. Where the thickness is equal to or exceeds the width of the deposit, there the slopes will intersect below the constructional surface and bring down the crest-line beneath the original surface. The average slope may be assumed to be 30°. Where this readjustment has taken place, it follows that an esker channel was originally narrow where the esker is now low, and wide where the esker is high. This gravitative rearrangement of the crest-line would not be produced in deposits whose thickness did not equal or exceed the width of the channel. The application of this principle to variations of crest-line is made possible by the uniform limitation of eskers to a cross-section within the range of this action. It is needless to enumerate examples in which the sharp ridge-like cross-section is the prevailing topographic feature for extensive segments of eskers. The annexed diagrams illustrate the geometrical principles involved in this explanation. The interpretation of this feature as observed in the Auburndale esker will be considered below.

FIG. 1.

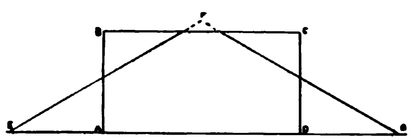
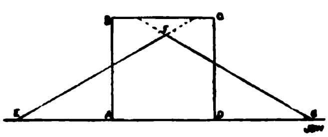


FIG. 2.



In these figures A B C D represents the assumed cross-section of the gravels and sands deposited in a tunnel of varying width before the ice has melted from the sides. E F G represents the cross-section after the sides of the original deposit have slidden down. In Fig. 1, F is above the constructional height, and the crest-line is there unchanged; in Fig. 2, F is below the constructional height and the crest is lowered.

The crest-line of some eskers agrees closely in elevation with the height of neighboring extraglacial deposits, moraine terraces, sand plains, and kame-fields. The exceptions often indicate a failure to attain the elevation reached by frontal and marginal deposits. Examples of this relation are to be seen at Auburndale, Mass., Pawtucket, and Providence, R. I. In a channel open to the sky, the limiting condition to the accumulation of detritus would accord with that of ordinary streams. When the ice melted away, the gravitative distribution of material on the sides might affect narrow and high segments of the deposit. Where this principle is not involved, the limit of construction must lie in the ice-sheet itself, as in the presence of an arch.

The second class of variations in crest-line corresponding with the relief of the terrane traversed by an esker is commonly observed and constitutes one of the most puzzling features. Eskers in southern New England tend to lie in nearly north-south valleys; but they occasionally are found crossing east-west depressions, often undergoing a change of elevation of nearly 100 feet. According to the view which maintains the superglacial origin of eskers, these last examples, like the first, originally filled channels in the ice at an elevation equal to the summits of the adjacent divides, the present position of the ridge being due to settling through the ice sheet, something like the passage of a wire loaded with weights through a block of ice. The objections to this view arise mainly from the frequent uniform preservation of the esker type throughout a segment having this distribution.[1] Such a change of position may be compared to the stretching of a linear mass from a chord to its arc. The eskers of this description, so far as I have been able to see their structure, do not exhibit evidences of this extension. The Cape Ann example is less steep-sided and well developed than the typical eskers of north-south valleys. I am not sufficiently acquainted with other examples to attempt to show their identity with those eskers which I believe to be of truly subglacial origin.

The Direction of Eskers.

Eskers tend to meander. Their sinuous and often tortuous course led Professor Shaler to name them "serpent kames."

[1] For other objections, see Salisbury, Geol. surv. of N. J., Ann. rept. for 1892, p. 42.

Eskers tend to lie in the direction of local glacial motion. This fact was long ago noted by Irish geologists, and is generally true of the more continuous and elongated eskers of this district.

This coincidence of direction is obviously due to a control exerted by the ice-sheet. Salisbury has suggested that supergla-cial streams would flow towards the front of the ice in obedience to the slope. It seems obvious also that subglacial streams would be held to the same course (1) by the motion of ice in valleys, and (2) by the tendency of the ice to close up passages oblique to its own forward movement.

Easting and westing of eskers.—Many eskers in meridional valleys tend to lie on one side. Generally, in the cases which I have observed, the easting and westing of eskers corresponds with a like tendency in the glacial striae. It is pronounced on the Meriden sheet,[1] the Providence[1] and Burrillville[1] sheets. The eskers in these cases are nearly or quite parallel with the valley walls. Notable instances of this distribution occur in the esker on the east bank of Compounce Pond, south of Bristol, on the Meriden, Conn., atlas sheet, and in the esker in the southern part of North Attleboro, Mass. This distribution follows from the rule of coincidence in direction with ice movement, and is in this district particularly noticeable with reference to the glacial lobes which lay in Cape Cod and Narragansett Bays, and in the Connecticut River valley. In these fields, the eskers diverge southwardly in the lobate axis, and converge southwardly toward the intermediate moraines. This phenomenon appears to be more pronounced in southern Massachusetts, Rhode Island, and Connecticut than north of the region here referred to. This difference is apparently due to the fact that inland and remote from the more or less lobate margin of the ice-sheet, the motion of the ice which controlled the position of drainage lines, was more nearly parallel across wide belts of country.

The fact that eskers, as in the case of those on the Meriden atlas sheet, lie in positions determined by the direction of motion in the ice-sheet, is evidence that the period of stagnant ice was short, otherwise the streams in the ice would have had time to wander from courses determined by the conditions of an active glacier. The presence of eskers in this position and their absence

[1] See forthcoming descriptions of the Pleistocene geology accompanying these atlas sheets.

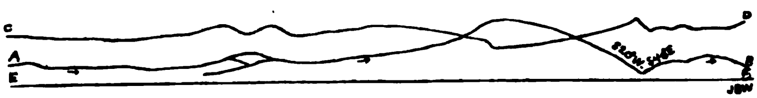
in the other portions of wide valleys, such as that east of Bristol, Conn., is further evidence that typical eskers were not formed by streams originating sporadically on the margin of the glacier during the period of stagnation. That streams originated on the ice and became superimposed on the subjacent terrane in northeastern Iowa has recently been shown by McGee.[1] Similar drainage lines arose on the margin of the ice in Plymouth County, Mass., and have determined the broad flat drift ridges and plains, lying between N. E. and S. W. lines of ponds and streams at the head of Buzzard's Bay,[2] but here the present drainage is in the depressions held open by the ice-divides of the original glacial drainage. In no part apparently of this glacial field did typical eskers originate independently of channels exhibiting a control exerted by an active ice-sheet. The comparative rates of construction in glacial sand-plains made out by Professor Davis[3] support this view, viz., that the period of stagnant ice in southern New England was brief.

There are minor irregularities in the course of eskers which as yet baffle explanation. It remains to discuss a few examples of meander in which there appears something like a rule of occurrence. Noting the Auburndale esker as a type, this deposit a short distance back from the head of the sand-plain described by Professor Davis, turns abruptly; thence it curves gracefully, convexly to the east for about half a mile, and the remainder of its course is somewhat tortuous. These changes of direction may be diagnosed as follows.

The Lines of an Esker.

In the Auburndale esker, maxima of change in the elevation of the crest-line correspond with maxima of change in course. In the accompanying diagram, the line A B in horizontal projection

Fig. 3.



[1] Eleventh Annual report U. S. geol. survey.

[2] See Plymouth atlas sheet.

[3] Bull. G. S. A., v. 1, p. 195–202, 1890.

represents the course of this esker from near Lasell seminary in Auburndale to its junction with the sand-plain about one mile south. The line C D represents in vertical projection upon the same plane the variations in elevation of crest-line for corresponding points of the line A B. The line E F may be taken in horizontal projection to give the average course of the esker; in vertical projection, to establish the base of comparison for the crest-line C D. These two lines thus drawn, showing the course and the elevation of the esker at each moment, may be said to give the *lines* of the esker.

Mr. Geo. H. Barton informs me that he finds a similar correspondence in the lines of the esker north of the Charles River, in apparently the same drainage line as the segment at Auburndale. Mr. F. C. Schrader, a graduate student in Harvard University, has prepared a manuscript map of the short esker between East Watertown station and the U. S. Arsenal, in Watertown, Mass. This esker terminates southwardly in a sand-plain. Near its junction, on the east side, is a spur or kame, probably marking the site of an alcove in the ice. The most interesting feature of the ridge is its passage by a small brook. Mr. Schrader found that the notch has been made where the course of the esker changes from S. 5° W. to S. 40° W. The esker also exhibits the commonly observed depressed crest-line near its confluence with the sand-plain. At the point where the crest-line falls off in elevation, the direction changes from S. 40° to 55° W., to S. 15° W. This esker is then a small example with accordant lines. The average course of this short ridge is S. 24° W.

Since formulating this graphic method of expressing the topographic features of eskers, I have not been able to apply it extensively to eskers in the field. It is true that many eskers do not display a consistent and regular variation in their lines. With this view in mind, my friend, Prof. W. H. C. Pynchon, now of Trinity College, examined the esker lying in the densely thicketed tract east of Randolph in the town of Canton, Mass. He found that the crest-line varied in height where the course changed, but there were numerous other variations not clearly coinciding with meanders.

In the case of the Auburndale esker it seems possible to draw inferences from its lines. Its meanders indicate a zigzag

course in the ice-sheet; its variable crest-line, now high, now low, indicates an ice-channel, wide here and narrow there. Since the maximum change in elevation coincides in positions with the maximum change in direction, the maximum changes in width of the channel, it may be assumed, occurred at points of maximum change of direction. In this respect, the esker presents conditions similar to those in river bends. The meanders of a stream in the ice may be modified by crevasses and forward motion, the first tending to divert, the second to maintain the stream in a given course. Corrasion and liquefaction would accentuate meanders at bends. Differential forward motion of the base of the ice-sheet divided by the subglacial channel would produce pinches and swells in the tunnel. Deposits made in channels so distorted would be constructionally wide and narrow, and ultimately high and low, upon the readjustment of their sides to gravity. Some slight motion of the ice against the sand-plain below Auburndale has been noticed by Professor Davis. It does not appear, however, from the succession of high and low points in this esker that shearing of the ice-sheet has here led to the lines above indicated.

Significance of the Cross-section of Eskers.

The cross-section of a typical esker tends to have the form of an isosceles triangle whose sides incline about 30° to the horizon. The altitude seldom exceeds one hundred feet, and is commonly not more than one quarter of that height. The base is at least one and a half times the altitude. The cross-section tends to uniformity. This remarkable feature indicates the control of some agency resident in the ice-sheet, in which eskers arise, and a satisfactory explanation of the cause of this limitation in cross-section must throw light on the question as to where in the ice eskers were deposited.

There seems nothing in the nature of existing superglacial drainage lines to restrict the deposits of a stream to a narrow and somewhat continuous channel. The conditions on the surface favor frequent perturbations of the drainage, and detritus accumulated on the surface of a glacier is apt to undergo more than one change of position and arrangement of its particles by reason

of adjustment to gravity. It is difficult to see how the deposits of a superglacial stream bed could be so held in the ice as to come to rest upon the ground as a distinct ridge.

Ice-cañons do not explain the uniformity of cross-section of eskers. I have already referred to deposits which appear to have originated in frontal superglacial streams which have cut down to the base of the ice and filled their channels. Some eskers occur in positions where it is possible to see that an ice-cañon would be at a given stage in the melting of the ice-sheet an impossibility.

An esker occurring at the base of a high and steep valley-wall, as in the case of the Compounce Pond esker near Bristol, Conn., is a case in point. The site of the present pond marks an ice-remnant lying between the esker and the eastern base of South Mt. The geological conditions at this locality are represented

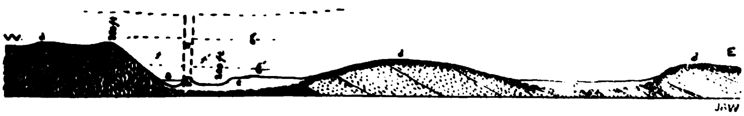


FIG. 4. Generalized section across the Triassic Valley of Connecticut showing position of Compounce Pond and esker. A, the Pond; b, the esker; c, stratified drift mostly extraglacial; d, till-covered uplands of crystalline Pre-triassic and Triassic rocks; e, ice-cañon, in this paper held to be untenable; f, ice-mass between esker channel and the escarpment on the west; f′, eastward extension of ice-sheet; g, g′, successive stages of lowering ice-sheet.

by the adjoined cross-section from west to east. Unless the ice-sheet were exceedingly thin when the esker was deposited, it is difficult to see how a cañon could be kept open with a wedge of ice resting against the slope of the mountain. The conditions are such that the inverted wedge of ice (f) would have slidden down the slope and eastwardly against the larger mass of ice (f′), with the result that the cañon would close and remain so, until the ice was too thin to obey the local slope. It is equally difficult to see why, if the esker were the product of a superglacial stream, the ridge should not have been formed next the valley-wall, without the intervening mass of ice. The drainage would have been lateral, with ice on one side, rock on the other. These facts seem explainable only on the supposition of a subglacial

origin of the Compounce Pond esker. The conditions are essentially repeated in the eskers on the Burrillville, R. I., sheet, at the western base of Whortleberry Hill in Smithfield.

Ice-tunnels in which the glacial drainage is piped through the ice have been observed by Russell[1] on the Lucia Glacier in Alaska. Deposits made in such a channel would naturally be limited by the arch so long as this remained intact. The dimensions of the tunnel described by Russell accord closely with the cross-section of some eskers. There arises, however, the difficulty of getting a deposit made in this situation upon the ground without destroying that uniformity of outline which distinguishes often considerable segments of some eskers. While the ice-tunnel shows what limits the cross-sections of eskers, it seems doubtful if it will explain many of the topographic features of eskers in this district.

The ice-arch tends to limit the cross-section of eskers to narrow ridges. The slopes of eskers are similar to those of moraine terraces, and like them indicate the deposition of the mass whence they have slidden upon the terrane they now encumber. Moreover this theory of the origin of eskers has the advantage of simplicity in that it supposes eskers to have originated where they are now found. The burden of proof rests, it seems to me, on him who would show that they were formed above the surface they now rest upon.

If under a given depth of ice more than a given width and height of arch cannot be maintained, any enlargement of the channel will be corrected by the creeping in of the ice or the deflection of the sides and roof.[2] In this way it seems possible to see why eskers should be limited to forms of tolerably uniform cross-section.

Terminals of Eskers.

Eskers tend to be associated with other deposits of water-laid drift, the lateral distribution of which in valleys is frequently symmetrical, as in moraine terraces and hillside kames, with

[1] Nat. geog. mag., v. 3, p. 105-108, pls. 12-15, 1891.

[2] Where the subglacial waters were under hydrostatic pressure, it is possible some enlargement may have been permitted. See Professor Shaler's paper "The conditions of erosion beneath deep glaciers," etc. Bull. mus. comp. zool., v. 16, no. 11, p. 203-205, 1893.

intervening ponds and swamps. The terminals of eskers present a wide range of association with glacial and preglacial formations. The northern end of eskers frequently rises from a bouldery, swampy field, where the drift is generally thin, amounting only to so much as came to rest upon the bottom upon the melting of the ice which immediately overlay the locality. In other cases an esker springs out from a kame-field, or begins at the down-stream end of a drumlin or other partial obstruction to glacial motion. We should expect to find eskers produced in subglacial channels sometimes taking their beginning near a pot-hole or site of a moulin in the ice-sheet, where the superglacial drainage became subglacial.

The southern end of eskers has more definite associations than the northern end. Eskers tend to terminate in moraine terraces, sand-plains, or kame-plains; hence the term "feeder esker," but it is probable that moraine terraces and sand-plains are fed by independent streams, since these deposits are well developed where no eskers are present. Eskers sometimes terminate abruptly, as if the deposit were made in a channel which had been closed by tensions in the ice.

Lineal Relations of Eskers.

The following-named types of channels which may arise in an ice-sheet, to each of which eskers have been ascribed by different writers, will make clearer the lineal relations of eskers.

1. Superglacial. 2. Englacial, or ice-tunnel. 3. Subglacial. 4. Ice-cañon.

The normal course of glacier-born water may be taken to be as follows: A stream begins upon the ice, as rain or sun-melted glacier ice, and forms a superglacial stream; lower down, the stream drops into a crevasse or well and gives rise to a moulin and possibly a pot-hole if it reaches the bottom of the glacier; the stream may become englacial, flowing in a tunnel, with here and there a roofless way. In the tunnel, its deposits will be limited in cross-section; in the open-air portion, the beds may assume the form of lake deposits; the stream may reach the front as an englacial stream, or may join the subglacial drainage. Streams flowing in channels under the ice will reach the front and may build frontal detrital deposits.

In the course of certain eskers, particularly where interrupted by a drumlin, I am informed by Mr. Barton, scour-ways or drainage creases are apt to occupy the interval. Such furrows are common in frontal moraines, where they are clearly not of superglacial origin but arise from the outflow of the subglacial drainage, as on the island of Martha's Vineyard.[1] Those creases arising in the interior of the ice-sheet are not so clearly referable to subglacial streams, and they require further examination.

The following provisional table of effects due to glacial rivers assembles the phenomena known to me.

Glacial Rivers are indicated
- within the ice-sheet, by
  - forms due to erosion:
    - pot-holes,
    - scour-ways, or furrows.
  - forms due to deposition:
    - kames,
    - eskers,
    - pitted-plains, kame-fields.
- outside the ice-sheet, by
  - forms due to erosion:
    - drainage creases.
  - forms due to deposition (partly in contact with ice):
    - terraces, lateral and frontal moraines; hillside kames (Stone),
    - sand-plains, osar-plains (Stone),
    - over-wash plains, aprons,
    - valley trains (Salisbury).

Relation of Eskers to Existing Water Courses.

Glacial and existing drainage lines usually exhibit discordance. Eskers commonly lie above the drainage line of meridional valleys, as below Woonsocket, R. I., near Ragged Mt., Conn. Existing streams frequently intersect eskers, by erosion, or by depression of the esker crest-line. The Bungay, Charles, and other rivers in Massachusetts cut across eskers. The trough or series of shallow kettle-holes marginal to an esker has sometimes become the course of a stream, which then becomes constructional by glaciation, and may be called an eskerside stream. Examples occur on the Providence sheet.

1 N. S. Shaler: Seventh Annual report U. S. geol. surv.

Esker Ponds (Tarns) and Swamps.

The surface skirting the base of an esker is frequently depressed below the adjacent region. Where the depression is lower than the level of the water-plane of the gravels which border the esker, the hollows become the seat of small ponds or tarns. Compounce Pond, south of Bristol, Conn., and Cunliff's Pond, below Providence, R. I., are examples shown on the atlas sheets of the U. S. geological survey. The ponds of this class are usually narrow or elongated parallel with the esker, and form an insignificant but common group. Where shallow, they have for the most part been converted into swamps during the postglacial epoch. Examples occur associated with the Auburndale esker and other ridges.

The ponds and swamps may flank both sides of an esker. In Cunliff's Pond, the water overflows a low place at the northern end of the esker, thus washing both sides of it. A conspicuous instance of this class of ponds occurs in the course of the Blackstone River near Pawtucket, R. I., at Lonsdale, associated with the esker described on p. 204. The ponds in this case are flanked on the east and west by well-developed terraces of the class denominated "lateral moraine terraces" by Gilbert. It is obvious that the depressions occupied by the pond are not due to

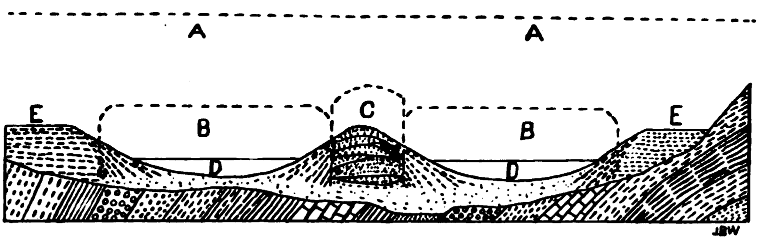


FIG. 5. Generalized section across meridional valley with lateral moraine terraces (or hillside kames), with medial esker, showing symmetry due to deposition of sands and gravels in the presence of melting valley-tongues of the ice-sheet. A A, ice-sheet previous to the stage B B, when isolated blocks hold open cavities between the esker and the terraces, E E. C is the tunnel in A A in which the esker originates. D D, esker ponds or swamps.

excavation by the river, but rather to the occlusion of sediments through the presence of masses of ice, having, at the time the deposition of the terraces ceased, the cross-section of the cavities now occupied by the ponds. This is but one of many instances in which it appears that the ice lingered longest near the sides of eskers. The annexed diagrammatic cross-section is typical of this class of facts. In fact, the existence of the group of esker-ponds and swamps depends altogether on this circumstance.

There are many reasons for believing that tongues of ice lay in the deeper valleys of southern New England when the uplands bordering them were practically bared of the glacier. The ice remained in the valleys longest because it was there thickest and took longest to melt. It was further preserved in these situations by the gravel and sand deposited on and about it. Another possible reason for the ice remaining longer in contact with eskers is the protection afforded by the esker itself, for a subglacial channel with its gravel filling would be more likely to retain the ice than a channel, either an ice-cañon or a superglacial way, open to the sun's heat and the influence of superficial running water. The water flowing in subglacial channels is necessarily cooler than the possible temperature of superglacial streams.

The eskers of this district appear to have been deposited when the ice-sheet had dwindled to the dimensions of stagnant, melting remnant glaciers. From this circumstance arose the frequent symmetry observed in the distribution of lateral terraces confronting either slope of an esker. The symmetrical distribution of deposits about the esker at Lonsdale, R. I., and Cunliff's Pond, in Providence, illustrates this feature.

Eskers and Glacial Lobes.

When the retreating ice-sheet of the last glacial epoch had its front still in southern New England, there were at least three glacial lobes, viz., (1) the Cape Cod lobe, (2) the Narragansett Bay lobe, (3) the Connecticut River lobe. The morainal deposits connected with the lobes are most distinct on the east. The loops of the accumulations have already been outlined by Chamberlin.[1] Inside and northward of the frontal deposits of

[1] Third Annual report U. S. geol. surv.

this time lie the eskers with their occasional attendant frontal sand-plains. The interlobate moraines of this district extend north and south where developed. The moraine skirting the west coast of Cape Cod Bay is the best developed of the region. Conformable to the law of correlation in distribution of glacial deposits, the eskers of this district diverge with the striae in the body of the lobes, or what is the converse of this statement, converge toward the interlobate moraines. The eskers of the Coleman's Height sand-plain in Scituate, Mass., on the east side of the interlobate moraine, have a north-east and south-west course (T. W. Harris). The eskers of Hingham, on the west side of the interlobate moraine tend to run to the south and east. Their position is too far north to be within the normal movement of the ice up to the moraine, and the east and west course of one of the eskers is probably due to a movement of the ice after its front had receded from the district marked by the lobate moraines.

A feebly-developed interlobate moraine skirts the west coast of Narragansett Bay. Along this district from North Attleboro, Mass., southward to Wickford, R. I., short eskers exhibit a marked tendency to lie on the west side of valleys or to run in a south-west course, conforming in direction with the glacial striae. From Woonsocket, R. I., southward, on the west of the probable line of the intermediate moraine, eskers lie towards the eastern side of the valleys in which they occur. In the district between Narragansett Bay and the Plymouth interlobate moraine, the eskers, as in the vicinity of the ponds about Middleboro, have a southerly course toward the front.

The interlobate moraines in the lower Connecticut valley have not yet been made out, but on the Meriden atlas sheet where the ice moved towards the west of south, the eskers run either in the same direction or hug the western walls of the valleys.

Eskers used as Roads.

In many places in southern New England eskers have been made the line of public highways. In some instances this choice has arisen from the necessity of finding a natural embankment across the swampy ground which commonly marks the depression in which the ice-remnants stood. In other cases, the road has

been diverted from a more suitable grade and course on to a somewhat level-topped esker apparently in order to save to the agriculturist the arable land in the vicinity. The road from Attleboro to Briggsville, Mass., for the distance of a mile follows the crest of an esker. Other examples occur about Meriden and Bristol, Conn.

Eskers in general exercise a sterilizing effect upon the communities they traverse. Except for their occasional use as natural embankments for roads, as a reservation for chestnut, oak, and other hardy trees, or as borrow-pits for coarse gravel, they are the least desirable of the glacial deposits.

Classification of Eskers.

Deposits made by glacier water are usually referred to by the name of the stream concerned in their formation; but eskers present some features requiring in our present understanding a different system of nomenclature.

The normal esker is a single, well-defined ridge. In some instances the ridge is double, indicating, as Professor Davis has suggested, a superglacial origin, or the widening of a tunnel until the arch became deflected downward dividing the stream into two parts. There are also examples of eskers which are composed of till instead of water-laid drift, to which I have given the name *false eskers*. One occurs as a short loop in the group of eskers lying on the large drumlin in Hyde Park, Mass. Such a deposit appears to preclude the action of running water. The channel abandoned by the water may have in this case been filled by the crowding in of till from the base of the ice during a slight forward advance. If it is supposed that the till came in from above, it is difficult to account for the lack of the action of running water.

Mr. Upham[1] is reported as ascribing "the eskers to ice-walled streams open to the sky, since no boulders or till fell from an ice roof upon them." Opposed to this view is the fact of a large angular block resting on the crest of the esker on the west of the road from Attleboro to Briggsville, Mass., and about one mile east of the former town. The perched position of this large angular block it seems to me must be explained, as in the case of

[1] Amer. geol., v. 12, p. 177, Sept., 1893.

other boulders in the glaciated district, by settling from overlying ice. To the same conclusion — that eskers were arched over by ice — I am driven by the previously-described false esker near Hyde Park. If this deposit of till were made in an open-air stream, running water would readily have surmounted the debris and at least its upper portion would exhibit traces of erosion or deposition.

Further than these remarks, it is beyond the province of the writer to attempt, at the present time, a classification of eskers.

Theories.

Of the theories to account for typical eskers those which do not recognize the origin of the deposits within the field occupied by the vanishing ice-sheet need not for obvious reasons at this time of writing be discussed. American and Scandinavian geologists are in essential agreement as to the deposition of eskers somewhere in the ice, views differing mainly as to the precise level in the ice-sheet.

Messrs. G. H. Stone[1], G. F. Wright[2], and G. H. Barton[3] think a superglacial origin presents the least difficulty. Russell[4] compares an esker with the deposit made in the tunnel of St. Lucia River in Alaska. Mr. Upham favors the ice-cañon view.

Mr. Upham's theory of the formation of eskers is as follows[5]:—

During the Champlain epoch, as the time of disappearance of the last ice-sheet has been named by Dana, its superficial melting was rapid throughout the warm portion of each year, while the subglacial melting went on at a very slow rate through both winter and summer, the same as it had been during the entire epoch of glaciation. Owing to the rapidity of the melting on the ice surface, and to the amount of englacial drift thus exposed and subjected to erosion and transportation, we believe that *the subglacial stream courses already existing* were inadequate for

[1] On kames or eskers of Maine. Proc. Amer. assoc. adv. sci., v. 29, p. 510–519, 1880. Professor Stone has recently argued for the subglacial origin of the same eskers.—Jour. geol., Chicago, v. 1, p. 246–254, 1893.

[2] *Op. cit.*

[3] Verbally communicated to me.

[4] Amer. geol., v. 12, p. 232, 1893.

[5] Amer. geol., v. 8, p. 381, 1891.

the drainage, and that they *were mostly obstructed and closed by the transportation and deposition of modified drift.* The waning ice-fields were then deeply incised by brooks and rivers pouring over them in the descent to their border and to the adjacent land lately uncovered by the glacial retreat. Hydrographic basins of the ice-sheet probably extended 50 to 200 miles or more from its margin, resembling those of a belt of country along a sea coast; but the glacial rivers, and their large and small branches, had much steeper gradients than those of the present river systems on the land surface, and often or generally they flowed in deep ice-walled channels, more like cañons than ordinary river valleys. Much englacial drift, which had become superglacial, was washed away by rains, rills, and small and large streams from the ice surface; and the osar gravel ridges are the coarsest sediments progressively deposited near the ice-front in such channels which were cut backward into the retreating edge of the ice by the superglacial streams.

Mr. Upham[1] states that "precisely the same explanation of the mode of formation of the osars was reached independently fifteen years ago by Dr. N. O. Holst[2] in Sweden and by the present writer [Mr. Upham] in New Hampshire. Four years earlier . . . nearly the same view had been first published by Prof. N. H. Winchell in Minnesota."

Professor Shaler in 1884 argued for the deposition of eskers by subglacial streams, but he did not then suppose the deposits were made inside the ice. Later the subglacial origin of eskers is stated thus by Professor Shaler:—

I am disposed to hold . . . . that the serpent kames have been formed in the following manner. The outflowing glacial streams excavated channels within the ice which they kept free as long as the currents were strong enough to scour their channels. In the closing stages of the ice-sheet, while the front was no longer advancing or perhaps inclined to retreat, these arches were filled in by material borne by the diminished currents.[3]

I have italicized in Mr. Upham's statement the portion which parallels with that made by Professor Shaler regarding the processes concerned in the deposition of drift at the close of the last ice-epoch. Mr. Upham describes the filling of subglacial stream passages with water-laid drift, but apparently ignores the deposits resulting from this process. The theory advanced by Professor

[1] Amer. geol., v. 8, p. 380, 1891.

[2] Förhandlingar Stockholm geol. förening, bd. 3, p. 97–112, 1875.

[3] Geology of Cape Ann, Mass. Ninth Annual report U. S. geol. survey, p. 550.

Shaler requires no further action for the production of eskers. It seems to the writer that most of the eskers which occur in southern New England are best explained on the supposition of subglacial channels filled with coarse detritus during the closing stages of the ice-sheet, even at so late a time as when the tunnels were exposed to the incursion of detritus from point to point where the roof had been melted through. In this manner, it seems possible to explain the diversity in gradation of materials in the esker, and the occasional high points or hummocks which cannot be explained by the methods proposed in the first part of this paper. Eskers were forming in the ice when terraces and sand-plains were forming outside of it, and often when the two series of deposits are so associated, there is a certain uniformity of level strongly suggestive of the melting or falling in of the arch *pari passu* with the construction of the deposit in the channel. In other instances this appears not to have happened.

Conclusions.

1. The diversity of materials, structure, and shape of eskers shows that the term esker (osars, serpent kames) is applied in common usage to deposits having at least slightly different modes of origin. 2. It follows from this, that each esker should be diagnosed upon its own merits, with regard to its external and internal structure, and its origin. 3. The diversity in the slopes, crest-line, and course of the same esker demands careful interpretation as to the mode of deposition and relations to the ice-sheet held by particular segments of the esker. 4. The steep slopes of some eskers indicate an adjustment to gravity upon the liquefaction of supporting ice-walls. 5. It follows from the limitations in cross-section of eskers, that where the deposit is now high and low, it must in places have been originally wide and narrow respectively. 6. In some eskers, maxima of change in direction correspond in moment with maxima of change in elevation of the crest-line. 7. So far as eskers are subglacial, they reflect conditions resident in the bottom of the ice-sheet. 8. The limitations in the cross-section of eskers demand some limiting agent in the ice-sheet, and the ice-arch alone fulfils the requirements. 9. Eskers tend to lie in meridional valleys, and to lie on one side of

a valley when the ice moved in that direction. 10. Eskers tend to give rise to secondary drainage effects, in ponds, swamps, and streams distributed along their flanks. 11. The typical eskers of southern New England are most easily explained by a subglacial origin, but segments occur where the cross-section departs from the limitations of the type and demands a channel open to the sky.

Prof. E. B. Poulton spoke on theories of evolution.[1]

Profs. H. F. Osborn, C. S. Minot, E. S. Morse, and A. Hyatt took part in the discussion which followed.

General Meeting, February 21, 1894.

President W. H. Niles in the chair. One hundred and five persons present.

It was announced that the following Corporate Members had been elected by the Council: Messrs. Frederick S. Bennett, Robert P. Bigelow, Severance Burrage, Charles B. Davenport, John Hobbs, T. A. Jaggar, Jr., William Patten, and F. W. Russell.

Prof. Charles R. Cross described and illustrated the physics of color mixture.

Prof. E. S. Morse discussed a recent advance in color printing by a photomechanical process.

The following papers were read:—

SPHARAGEMON: A STUDY OF THE NEW ENGLAND SPECIES.

BY ALBERT P. MORSE.

I. Prefatory.

The following paper arose from study of the New England Acrididae with a view to publication upon this part of the New England insect-fauna.

[1] This paper will be published at some future time.

Although the group as found in New England is but a small one, a considerable amount of literature bearing upon it has accumulated, in many cases contradictory and confusing in character, and leaving many gaps to be filled in a thorough and systematic account.

The only scientific way of obtaining such knowledge of the group as under these circumstances seems desirable is through the medium of a collection comprising all the various forms from every part of the district under consideration. I have endeavored during the last two or three years to obtain such a collection, and to that end considerable portions of two summer vacations, — in addition to more or less time throughout the season in the vicinity of Wellesley, — have been spent in the field in various parts of New England, and several thousand specimens have been brought together. I have separated out all belonging to the genus Spharagemon and these, with the data connected with their capture, form the basis of this paper, which may prove to be the first of several of similar character.

Whenever practicable I have made an examination and comparison of the type specimens. In some cases this has been easy, in others impossible, owing to their destruction.

While there are still some points left unsettled, these are of minor importance in relation to the end in view (a thorough knowledge of the New England species), and as considerable time would unavoidably elapse before they could be definitely settled, and as a number of definite results have been obtained, it has seemed best to give to other students the benefit of these results by publication at this time. Later on, if sufficient material can be obtained, I hope to give a synopsis of the genus.

In my study of the New England Acrididae during the past two years I have collected nearly five hundred specimens belonging to this genus. In addition to these specimens I have in my collection a few taken in Massachusetts by Mr. S. W. Denton, several from Indiana sent by Mr. W. S. Blatchley, and representative specimens of several western forms sent by Prof. L. Bruner of Nebraska. I have also had for examination a number received from Cornell university through the kindness of Prof. J. H. Comstock, and all in the collection of Mr. Samuel Henshaw, of Cambridge. In all five hundred and sixty specimens of which over five hundred are from New England localities. I have seen

those in the Museum of comparative zoology referred to by Scudder in his "Materials for a monograph of the Orthoptera of North America," and all that remain of those in the Harris collection. Lastly, but of prime importance, I have had the privilege of studying all in Mr. Scudder's collection, among them the types of the species described by him, without an examination of which it would have been impracticable to prepare this paper.

The results of my studies, both in the field and of cabinet specimens, are here presented. Briefly stated they are the reduction of one so-called species (*balteatum*) to a synonym of another (*bolli*), the addition of one new species (*saxatile*) to the New England fauna, and the detection of what I believe to be another undescribed species (*oculatum*) which has been taken in close proximity and will probably be found to occur in southern New England.

I have added a table of comparisons, which will probably be helpful in determining specimens, and a few sketches of details of structure which it is hoped will assist in the comprehension of the specific differences presented by the New England species in the parts represented.

Owing to the difficulties and consequent confusion connected with the correct identification of the various species of this genus, I have not given the synonymy and bibliography of the species but merely of the specimens examined, whenever such notes seemed desirable.

For the accommodation of others working on this family, and in the hope that future confusion and synonymy may be to some extent avoided, I have decided to send representative specimens of the three common New England species to collections in various parts of the country. This I am enabled to do by reason of the considerable number of specimens in hand. And I hope that this practice of obtaining a large number of types and distributing them, or at least representative specimens, will be followed by other workers. Specimens will be sent to the following collections:—

Museum of comparative zoology, Cambridge, Mass.
Massachusetts agricultural college, Amherst, Mass.
American museum of natural history, New York, N. Y.
Cornell university, Ithaca, N. Y.
American entomological society, Philadelphia, Pa.

National museum, Washington, D. C.
Mr. W. S. Blatchley, Terre Haute, Ind.
Minnesota state experiment station, St. Anthony Park, Minn.
University of Nebraska, Lincoln, Neb.
Prof. Lawrence Bruner, Lincoln, Neb.
Louisiana state experiment station, Baton Rouge, La.
Leland Stanford, Jr., university, Palo Alto, Cal.

I desire to express my obligations to all who have favored me with specimens for examination, or in other ways contributed to increase the value of this paper, and among these especially to Prof. Bruner, Mr. Henshaw and Mr. Scudder, to whose kindness, encouragement, and courtesy, very much is due.

II. Introductory and Explanatory.

The genus Spharagemon was founded by Scudder in 1875, the type of the genus being the species considered by him to be the *Gryllus aequalis* of Say. Six species were placed in it, four being described for the first time. Of the six species, the type (*aequale*) and two of the new ones (*bolli* and *balteatum*) were stated to inhabit New England; the remaining ones were from states west of the Mississippi River.

One of the western species (*collare*) has since been reported (Bull. no. 4, ent. div. U. S. dept. agric. p 30, and Bull. 90, N. J. agric. coll. exp. station, p. 34) as occurring on Cape Cod, but for several reasons I am disposed to question the correctness of the determination of the specimens referred to this species, see page 234.

The first species of this genus known to science was described by Thomas Say (Journ. acad. nat. sci. Phila., ser. 1, v. 4, p. 307,—Amer. ent., ed. Leconte, v 2, p. 237) under the name of *Gryllus aequalis*. The specimens from which it was drawn were collected by him while on Long's Expedition to the Rocky Mts.,[1] but their exact locality Say does not indicate.

They were deposited in the collections of the Academy of natural sciences of Philadelphia, but have been destroyed.[2]

[1] This expedition set out from Pittsburg, Pa., and passed through parts of Ohio, Kentucky, Indiana, Illinois, Missouri, Nebraska, and Colorado, to the base of the mountains, thence south and southeast, returning through Kansas, Arkansas, etc.

[2] This point I have verified by correspondence.

Say's description does not, as we now understand the species, strictly characterize any one of them, and it is highly probable that he confused several species under this name. He has been known to do this in the case of other insects.

Harris sent him a locust from Massachusetts to which Say, correctly or incorrectly, applied this name. Harris re-described the species from this specimen, but his description varies somewhat from that of Say. This specimen has also been destroyed,[1] but it was examined by Scudder, who, having worked over the Harris collection and made a specialty of the order since, and being also the first reviser of the species of this genus, is to be considered as our best authority regarding the identity of *aequalis*. In his revision he retained the name for one of the New England species. This species, as found in New England, differs slightly from Say's description.

Say states: "Hind thighs within with four black bands." The New England form usually has the proximal two bands broadly connected with fuscous. This character is somewhat variable individually, however, and the disposition of the fuscous connection is such as to leave the appearance from above of four bands. Another point may cause doubt: Say states, "The thorax is not gradually raised into a carina, but the line is abrupt and of little elevation." This at first seems incorrect when applied to this species, but it must be remembered that Say described as in the same genus (Gryllus) species which show such extreme development of the carina as *Tropidolophus formosus*. This species also was described from material obtained on the expedition referred to. Possibly Say had it in mind when describing *aequalis*. At all events, by comparison with this species it will be seen that Say's description of this structural character in *Gryllus aequalis* is applicable to any species of the genus Spharagemon. The New England form of *S. aequale* is quite distinct from the other New England species but is approached closely by a western one, *collare*.

[1] The specimen of "*Locusta aequalis*" is entirely destroyed, but No. 73, ♀, is catalogued as "*Locusta hybrida, mi. n sp.* . . . in company with *L. aequalis*," from which it seems probable that Harris recognized two species. All that remains of this are portions of the wings, from which it is impossible to decide to which species they belonged, except that they are not the wings of *bolli*, as clearly distinguished by the extent of the fuscous band.

Owing to a lack of sufficient material, I cannot decide positively the relation of this form to the western forms grouped with it by Mr. Scudder under the name *aequale*, or state definitely whether it is or is not found in the region traversed by Say.

Since it presents certain differences I have thought it best to consider it a subspecies and apply to it a name, *scudderi*,—which, under the circumstances, seems most appropriate and desirable. If it prove to be a geographical variety or subspecies, well and good; if, on the contrary, it be found along Say's route as well as in New England, this name can be dropped; and should it prove to be a distinct species the name can stand, receiving specific value.

I have given a full description of this form and have used only this name, *scudderi*, wherever reference is made to the New England form alone.

III. Generic.

The student will find it desirable and probably necessary to consult the paper referred to in which Scudder founded the genus,[1] and as the generic description is quite long I have omitted it here, but it seems desirable to note at this time one or two points in connection therewith. It is stated in the description of the genus that the median carina of the pronotum is divided by the principal sulcus into two parts, the *front* portion a little longer. This is evidently a slip, the reverse being true in all species seen, and almost the characteristic of the subfamily.

The eyes are there characterized as rather small. This is true of the type of the genus, *S. aequale*, and those of *S. collare* are quite small; they are of moderate size, however, in *S. bolli* as well as in the two new species described here (*saxatile*, *oculatum*), in the males of which they are rather large and somewhat prominent.

IV. Specific.

Spharagemon aequale Say. (Scudder.)

S. scudderi subsp. nov.

Spharagemon aequale Say. Scudder, Proc. Bost. soc. nat. hist., v. 17, p. 468

[1] Spharagemon,—a genus of Oedipodidae; with a revision of the species. Proc. Bost. soc. nat. hist., v. 17, p. 467–471, 1875, also in Scudder's Entomological notes, 4, p. 66–70.

Oedipoda aequalis Uhl. (Say) in part. Scudder, Boston journ. nat. hist., v. 7, p. 470.

Scudder made this species the type of the genus at the time of establishing it and revising the species. As he gave no description of it (save its generic characters with a diagnosis and a few remarks under *bolli*) and as Say's description does not well characterize the species, I shall describe the New England form here.

Body compressed. Head of moderate size, compressed above, tumid at the sides below, especially in ♀, the occiput full above; vertex as declivent as occiput, broad, tapering rapidly, shallowly sulcate; the eyes separated by more than double the width of the basal antennal joint. Face very nearly vertical, in profile scarcely convex and rounded at meeting with vertex; costa of moderate breadth, slightly narrowed above antennae, shallowly sulcate except at upper end: lateral carinae sharp, distinct. Eyes rather small, about two fifths the depth of face from crown (top of head between eyes) to clypeus, the crown rising above them. (See fig.) Antennae somewhat shorter than hind femora, fuscous at tip, paler, often ochreous, rusty or even red basally, scarcely annulate at extreme base.

Pronotum. (See fig.) Disk of pronotum moderately flat, least so on posterior half of prozona, the front margin considerably angulate; the posterior process acute, sharp-pointed, the sides excavate. Disk of metazona often slightly arched in median section and rather broadly joined to the median carina. Median carina high, arched on both lobes; strongly compressed on metazona and anterior half of prozona, on the posterior half of prozona sloping down to sides of disk. Dorsal edge of carina of prozona usually slightly arched and forming a backward-directed tooth in front of the notch. Incision oblique, deep, often fenestrate by reason of the lobes slightly overlapping.

Tegmina passing hind femora by about one third their length, rather angulate on costal margin near base.

Wings with the disk pale yellow, this margined distally by a broad fuscous band, which is broadest on costal margin of wing, and narrows from its meeting with the hind margin of wing to the anal angle; it sends off a broad short shoot one third or one half way to base in the median and ulnar areas (subfrontal shoot). This dark band is usually rounded on its distal margin, where it joins the hind margin of wing, and is palest in color next the anal angle which it sometimes scarcely reaches, but always more nearly than in *bolli*. The lateral and antero-posterior dimensions of the yellow disk are about the same and equal half the extreme length of wing. The fuscous band occupies the third quarter on the costal margin. The apical portion of the wing is transparent, usually more (♂) or less (♀) infuscated, often with fenestrate spots.

Hind femora on the outer side with four transverse fuscous bands, the proximal least distinct and more or less obsolete ventrally; on the inner side with apparently but three fuscous bands, the basal one very broad and formed by the union of the proximal two, leaving only spots on the dorsal and ventral edges of femora free from fuscous.

Hind tibiae deep coral-red, sprinkled at base with fuscous and pale, sometimes showing indications of a pale basal annulus next to base. Spines tipped with black. Hind tarsi red, often luteous beneath.

Color a light rusty or yellowish brown, granulated and spotted with darker brown and fuscous flecks, the spots usually with sharp outlines and often fenestrate. The color varies to bright rust-red and to brownish black. The face may show indications of a transverse dusky band above clypeus but is usually merely punctate and marmorate. Disk of pronotum often with an indistinct X of the paler ground-color, bordered externally by the lateral carinae. Sides of pronotum with two more or less distinct dusky bands; the upper bordered by the lateral carina, darkest above, often continued forward on side of head, where it is margined above with pale, to the hind border of eye; the lower halfway down, very irregular in outline; the paler streak between them curving downward anteriorly and continued on cheek with pale. On the tegmina the spots are aggregated into three more or less distinct transverse fasciae, crossing at about ¼, ½, and ⅔ the distance from base; apex clear, maculate with fenestrate fuscous spots.

88 ♂, 98 ♀. The following are measurements of New England specimens. Antennae: ♂, 11.5–12.5 mm.; ♀, 11–11.5 mm. Hind femora: ♂, 13–14; ♀, 14–16.5. Tegmina: ♂, 23–24.5; ♀, 25.5–28.5. Body: ♂, 21–23; ♀, 27–29. Total length: ♂, 28.5–30.5; ♀, 32–35.5.

These specimens bear dates ranging from July 23 to Sept. 22. This species is to be looked for from the second week in July until the end of the season. I have taken it in Connecticut at Niantic and Thompson; in Massachusetts at Sherborn and Wellesley, and have received it also from Easthampton (S. W. Denton). Mr. Henshaw took his specimens on Nantucket in September. Mr. Scudder has taken it in Vermont and on Cape Cod.

All of my specimens were taken in open fields, mowing and pasture, on rather sandy soil, and though somewhat local in distribution were quite plentiful in numbers, the species differing somewhat in this particular from *bolli* which seems to be more widely spread and more scattered over the country.

SPHARAGEMON BOLLI Scudder.

Spharagemon bolli. Scudder, Proc. Bost. soc. nat. hist., v. 17, p. 469.

Spharagemon balteatum. Scudder, Proc. Bost. soc. nat. hist., v. 17, p. 469.

Spharagemon bolli Scudder. Blatchley, Can. ent., v. 24, p. 30.

Spharagemon balteatum Scudder. Blatchley, Can. ent., v. 23, p. 78.

Spharagemon aequale. Comstock, Introd. to ent., p. 103, 104.

Oedipoda aequalis Uhl. (Say) in part. Scudder, Bost. journ. nat. hist., v. 7, p. 470.

In regard to this synonymy I would say that I have examined specimens referred to these names by the authors in the works cited.

Scudder described this species from 4 ♂ and 4 ♀ specimens from Texas, stating that he had smaller specimens from Vermont and Massachusetts, and separated from it as another species (*balteatum*) a form described from 1 ♂ from New Jersey and 9 ♀ from Maine, Vermont, Maryland, and Texas, in which the tips of the wings were less infuscated. He noted also a difference in the height of the crest of the pronotum.

From an examination of the specimens before me and from observations taken in the field in the past two seasons I am forced to consider that these two forms, — as represented in New England, at least, — are but one species, and that *balteatum* is unworthy even of varietal rank, a position to which Saussure assigns it. My reasons for so thinking are these: (1) There are no structural differences in the two forms, but the pronotal crest is higher in the ♂ than in the ♀ and varies somewhat in different individuals of the same form; (2) The two forms intergrade in wing infuscation; (3) Both forms are taken in the same spot at the same season of the year; (4) The greater proportion of the males have the wings as described for *bolli* and the greater proportion of the females as described for *balteatum;* (5) Two other New England species have the wing-tips of the males much more constantly and heavily infuscated than those of the females.

These statements are based on nearly one hundred and fifty specimens personally collected in various parts of New England, a lot of 13 ♂, 9 ♀ from one spot in Norway, Me., one of the localities from which *balteatum* was described being of interest in this connection, and also similar lots of 12 ♂, 7 ♀ from Fryeburg, Me., and of 19 ♂, 17 ♀ from a locality in Connecticut. In addition to these I have examined a considerable number of

specimens from New York and some from Indiana, and, as a matter of course, the types in Scudder's collection.

In connection with the description of this species by Scudder I must take exception to one of the statements made in comparing it with the species here designated as *scudderi*, viz.: — in this species "the front half of the median crest of pronotum is less pinched posteriorly." This may have been a slip, for the opposite is true — the statement applying to *scudderi* when compared with *bolli* (see fig.).

120 ♂, 90 ♀. The following are measurements of a number of New England specimens. Antennae: ♂, 10–13 mm.; ♀, 11–13 mm. Hind femora: ♂, 12.5–13.5; ♀, 12.5–17. Tegmina: ♂, 20.5–25; ♀, 23–28. Body: ♂, 20.5–22; ♀, 27.5–33. Total length: ♂, 26–30.5; ♀, 29–38.

As will be seen on comparing these measurements with those of *scudderi*, it is much more variable in size.

The New England specimens bear dates ranging from July 15 to Sept. 27. The species is to be looked for from the first week in July until snow falls.

I have taken it in Maine at Fryeburg, Norway, and on Speckled Mt., Stoneham; in Massachusetts at Dedham, Medfield, Provincetown, Sherborn, Waltham, and Wellesley; in Rhode Island at Kingston and Wickford; in Connecticut at Montville, New Haven, Stamford, and Thompson. I have also received it from Easthampton and So. Hadley, Mass. (S. W. Denton), and Forest Hills and Jamaica Plain near Boston (in Henshaw's collection).

This species I have found more widely spread and less plentiful in numbers locally than *scudderi*. It has a special fondness for bushy pastures and the edges of woodlands on sandy soil, but may be found on almost any ground of a barren character, even at a considerable elevation. It is plentiful in one locality at Provincetown, Mass., and there takes on a bright reddish brown hue, the color of fallen huckleberry leaves.

SPHARAGEMON SAXATILE sp. nov.

Oedipoda aequalis Uhl. (Say) in part. Scudder, Bost. journ. nat. hist., v. 7, p. 470.

Spharagemon bolli Scudder, 2 ♂, 1 ♀, in Scudder's collection.

At one time, influenced by Harris's description, I regarded this species as *aequalis*, and sent specimens labeled *Dissosteira aequalis*

to Prof. Lawrence Bruner and to the collection of Cornell university. These I have re-examined in connection with this paper and labeled as types.

Size moderate. Rather glabrous. Body stout, less compressed than *scudderi*. Color brownish or blackish fuscous in spots and bands on an ash-gray ground, darker above, lighter below, the abdomen drying somewhat yellowish. Usually a more or less distinct ashy X on the disk of pronotum.

Head of moderate size, compressed above, expanded below; cheeks rather tumid below; the vertex rather broad, more declivent than the occiput, anteriorly shallowly excavate with a perceptible median ridge. Face slightly convex in profile; costa rounded at its union with the vertex; lateral carinae distinct. Eyes of moderate size, in the ♂ subprominent. Antennae long, passing pronotum, in the ♂ reaching fossa 3. Head blackish above; face and cheeks pale ash-gray, irrorate and punctate with black and deep brown. Eyes griseous. Antennae fuscous, black at tip, the proximal two thirds annulate with pale, the annulations broadest at base and becoming very narrow distally.

Pronotum (see fig.) stout, slightly compressed anteriorly, broad and scarcely compressed posteriorly. Front margin of disk slightly angulated, hind margin right-angled (♀) or slightly acute (♂), the apex rather blunt. Median carina rather low, scarcely compressed at the base on prozona, compressed and well developed on anterior half of metazona, almost disappearing on posterior half; sinuous above on prozona, arched and highest anteriorly on metazona, the principal sulcus cutting it in a vertical incision, the notch deep and rather widely open, its front margin formed by a distinct backward-directed tooth. The disk of the metazona is considerably arched in median section, rendering the posterior half of its carina extremely low. The disk of the prozona slopes rather gradually up to the carina, which is scarcely compressed on its posterior half. Lateral carinae showing on the metazona, where they are rounded, and indistinctly on the anterior third of prozona. The sulci rather deeply impressed, giving a rugose appearance. Disk usually marked with ashy in the form of an X, widest behind, bordered by the lateral carinae. Apex of metazonal process often ashy. Lateral lobes pale, more or less marmorate with black; two indistinct black bands parallel to lateral carinae, the dorsal bordering them, the ventral midway down, both more distinct on prozona.

Tegmina passing hind femora by one fourth to one third their length, more or less transversely trifasciate with fuscous, at the base brownish fuscous; the tip transparent with numerous fuscous, more or less fenestrated spots; venules of base often lighter than membrane, giving a reticulated appearance.

Disk of wings sulphur-yellow, the veins and venules rarely infuscated, its antero-posterior diameter about equal to its proximo-distal. Beyond, a broad fuscous band reaching the anal angle and sending off near costal

margin a broad short shoot about half way to base, the apical margin of the band being roughly straight. Apical third of wing transparent, the veins and venules mostly fuscous, the apex more (♂) or less (♀) infuscated, either fumose or maculose, if the latter the spots often fenestrate. The apical fuscous portion is sometimes connected with the transverse band by streaks along the median and axillary veins, especially the latter:

Hind femora ash-gray on the outer side, yellowish on the inner side, with four transverse blackish fuscous bands, the two proximal more or less incomplete ventrally, and usually connected on the inner side of femora. Hind tibiae slightly pubescent, the base black followed by a pale annulus, coral-red beyond, sometimes with a slight infuscation distad of the annulus on the outer side. Spines tipped with black. In one specimen the left hind tibia is normally colored, while the other has the pale annulus replaced by fuscous. Hind tarsi pinkish above, luteous below. Legs 1 and 2 ash-gray, punctate with fuscous.

91 ♂, 60 ♀. Measurements in mm. Antennae: ♂, 12–14.5; ♀, 12–14. Hind femora: ♂, 11.5–14; ♀, 14–17. Tegmina: ♂, 21.5–25.5; ♀, 25–31. Body: ♂, 20–24; ♀, 28–34. Total length: ♂, 27–32.5; ♀, 32–39.

It will be seen that the species is quite variable in size, averaging larger than *bolli* or *scudderi*, and with longer antennae.

I have taken it at various dates from July 24 to Sept. 20: — in Massachusetts at Blue Hill, Needham, Sherborn, Waltham, and Wellesley; in Connecticut at Greenwich, New Haven, and Thompson. Six specimens in Mr. Henshaw's collection are from Blue Hill, Jamaica Plain, and Malden, Mass. In Mr. Scudder's collection there is a ♂ from Maryland, taken by Uhler.

I have named this species *saxatile* for the reason that it seems to find life most to its taste in unsettled, somewhat wooded districts of a rocky, often elevated character. Here it finds a congenial home and may be seen during the latter half of the season crawling actively about over the lichened ledges, whose tints harmonize with its own, or flying from one to another, stridulating loudly as it goes.

In its fresh state it is one of the handsomest of our New England locusts, and even cabinet specimens vividly recall the cool gray of the rocks, the glory of the goldenrod, and the tints of reddened stems of trailing vines. So well do the colors of its body match those of its chosen haunts,—the pale greenish gray and ashy of the paler rock-constituents and their lichen coverings, the brown and black of other lichens and the darker elements hornblende and mica, or iron-stained disintegrated particles,—that it is quite difficult to distinguish when at rest,

and being an extremely alert insect some strategy is required to capture it.

This species is similar in coloring and superficial appearance to *Circotettix verruculatus* Kirby, which it also resembles in preferring similar haunts. It is readily distinguished from it, however, by the color of the hind tibiae (in *verruculatus* pale yellow or gray, banded with black) and the character of the dark wing-band (in *verruculatus* narrow and made up of subcontiguous spots).

SPHARAGEMON OCULATUM sp. nov.

Syn. Several specimens from Indiana received from W. S. Blatchley were referred by him doubtfully to *S. aequale*.

1 ♂, 2 ♀, in Scudder's collection were labeled "*S. collare*, N. J."

I am disposed to think from the last mentioned fact that perhaps this is the species referred to by Prof. J. B. Smith as *S. collare* (Bull. no. 4, ent. div. U. S. dept. agric.; Bull. 90, N. J. agric. coll. exp. station, p. 34).

Small. In the structure of the pronotum closely allied to the type. Pale yellowish or pinkish brown sprinkled and spotted with darker brown or fuscous; paler, somewhat yellowish, below. One specimen is much more dusky, brownish fuscous above, somewhat paler below,—thus very similar to the type in color.

Head of moderate size; equal, the dorsal half being less compressed than in the type. (See fig.) Eyes large, rather prominent, in depth equaling half the face from crown to clypeus (♂), or a little less (♀). Owing to prominence of the eyes the vertex seems lower and the occiput less tumid than usual in this genus. Top of head seen from above with the vertex about as broad as the eye, in ♀ a little more, in ♂ a little less, and varying individually. Facial costa sulcate in ♂, less sulcate in ♀, but rather more so than in *scudderi*. Lateral carinae of the face sharp, distinct. Face indistinctly fasciate transversely, a band of yellowish brown or fuscous passing below antennae from eye to eye, another band halfway down, broadest on median portion of face, and irregular dusky markings on clypeus and labrum. Antennae of moderate length, fuscous at tip, lighter toward base, with indistinct annulations.

Pronotum very similar to that of *scudderi*. The disk rather flat on metazona, somewhat sloping on prozona; slightly angulate in front, acute-angled behind, more so in ♂ than ♀ and somewhat variable. Median carina compressed, high, arched, more so on metazona than on prozona; its dorsal edge often slightly sinuous on the prozona, on the hinder half of which it is less compressed at base, the disk there rising

rather gradually to form the carina; notch oblique, very narrow or even fenestrate. Sides of pronotum bearing two indistinct, dusky bands, the dorsal bordering the lateral carinae and continued forward on sides of head to posterior borders of eyes, the ventral halfway down and very irregular in outline.

Tegmina passing the hind femora by about one third their own length, trifasciate with fuscous spots, the posterior (dorsal when closed) half sometimes brownish red; the anterior margin distinctly angulated near the base.

Wings very similar in the form and extent of the fuscous band to those of *scudderi*, the band broad, nearly or quite reaching the anal angle, rounded on distal margin at meeting with edge of wing. Apical portion of wing clear, slightly maculate with small, irregular fuscous spots, about equally so in the two sexes (in the specimens seen).

Hind femora pale on outer side, showing remnants of the four transverse fuscous fasciae, most distinctly in the dorsal groove; on the inner side quadrifasciate with black on a sulphur-yellow ground, the basal fasciae incomplete ventrally, and the proximal two not connected with fuscous. Hind tibiae pale red or pink, usually showing indications of a pale annulation next to base, which is more or less sprinkled with fuscous. Tibial spines with extreme tips black.

In most of the specimens the legs, especially the posterior, and the ventral portion of the body are markedly pubescent, exceeding the type in this respect.

Measurements. Antennae: ♂, 9.5–12 mm.; ♀, 10–13. Hind femora: ♂, 11–12; ♀, 12.5–15. Tegmina: ♂, 18.5–20.5; ♀, 23–25.5. Body: ♂, 18–20; ♀, 24–29. Total length: ♂, 23.5–26; ♀, 29–31.5.

2 ♂, 2 ♀, Marshall Co., Ind., Aug. 1, 1892; alcoholic.

2 ♂, 2 ♀, Fulton Co., Ind., dry, antennae damaged.

1 ♂, 1 ♀, returned. All these Indiana specimens received from W. S. Blatchley.

1 ♂, 2 ♀, in Scudder's collection, labeled "*S. collare*, Beutenmüller, N. J."

1 ♂, with the three specimens above, unlabeled, perhaps of the same lot.

Mr. Beutenmüller informs me that the specimens above referred to are from Staten Island. Search should be made for this species on sandy soils in the southern parts of the three southern New England states.

This species bears a close resemblance in the structure of the pronotum to *scudderi* from which it may readily be distinguished by its small size, the less compressed head, and the greater size and prominence of the eyes. (See fig.) The differences shown by the inner sides of the hind femora are also very helpful.

From *collare* also it may be distinguished by its small size, the much greater proportionate size and prominence of the eyes, and the more equal and less tumid head. (See fig.)

SPHARAGEMON COLLARE Scudder.

I have never taken this species in New England, and I regard its presence here as very improbable, but since it has been reported to occur on Cape Cod and in New Jersey (Bull. no. 4, ent. div. U. S. dept. agric.; Bull. 90, N. J. agric. coll. exp. station, p. 34), I mention it.

Prof. J. B. Smith writes me that the specimens referred to above were collected by him while in the employ of the U. S. dept. of agriculture and forwarded to Washington where the determinations were made. Dr. C. V. Riley, who kindly looked into the matter for me, reports that careful search through the National museum collections fails to bring them to light. Consequently I have been unable to examine and identify them. Owing to the difficulties in distinguishing the species of this genus I regard the correct identification of these specimens extremely doubtful. I have indicated my reasons, under *S. oculatum*, for thinking that possibly that species may be the one referred to.

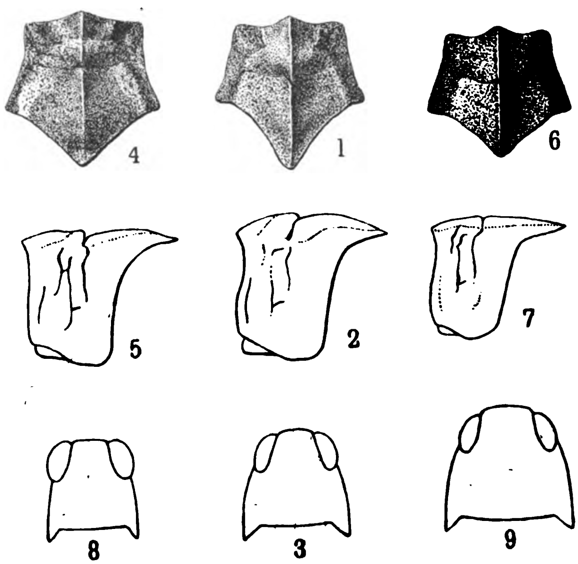


Fig. 1, 2, 3, *S. aequale scudderi*. Fig. 4, 5, *S. saxatile*. Fig. 6, 7, *S. bolli*. Fig. 8, *S. oculatum*. Fig. 9, *S. collare*. 2⅔ diameters.

V. Comparisons of Species.

These comparisons will be of most value in connection with examples of the several species, but also may prove to be of some assistance in determining specimens. It should be borne in mind that I had of *oculatum* and *collare* but a very limited number of specimens before me, and consequently some latitude should be allowed statements concerning these species.

S. collare Scudder.

Owing to the improbability of the occurrence of this species in New England I have thought it not worth while to give extended comparisons with the other species, but as the description is not given in Scudder's paper and may not be available to some, I will point out briefly how it may be distinguished from the New England species.

It has been compared with *oculatum* under that species. From *saxatile* it may be known by the greater height of the metazonal carina, the small eyes, tumid cheeks (see fig.), and the lack of a pale basal annulus on the hind tibiae. From *bolli* by the much fuller head and small eyes, the obliquity of the notch of pronotum, and the lack of pale and fuscous annulations on hind tibiae. From *scudderi* by the fuller head, smaller eyes, less elevated carina, and by the markings of the inner sides of hind femora, — in *scudderi* the proximal two fuscous bands being more or less broadly connected, in *collare* almost always distinctly separated.

	saxatile	*bolli*	*oculatum*
scudderi	1	2	3
saxatile		4	5
bolli			6

1.—*S. saxatile* vs. *S. aequale scudderi.*

In *saxatile* the dorsal portion of the head is less compressed. The eyes are noticeably larger and more prominent. The vertex is broader between the eyes, and less acute at the front. The antennae are much longer proportionally, and noticeably annulate; their color blackish fuscous and pale: in *scudderi* brownish or blackish fuscous at tip, rusty brown or even red at base and scarcely annulate.

In *saxatile* the pronotum is less compressed, especially behind; the disk less flattened, its anterior margin less angulate; the pos-

terior process rectangular and more bluntly pointed, its sides straight, — not acute and with the sides excavate as in *scudderi*. The MEDIAN CARINA is much lower and less developed throughout (see fig.), the disk sloping gradually up to form it. The incision is nearly vertical. instead of slightly or even considerably oblique. The notch is open, never fenestrate, the two portions of the median carina never overlapping as is often the case in *scudderi*.

In *saxatile* the TEGMINA are more distinctly fasciate, the fasciae usually broader. The WINGS are very similar to those of *scudderi*, but the transverse fuscous band has its apical margin straighter (in *scudderi* being rounded next hinder edge of wing), the subfrontal shoot often more acutely terminated and extending further toward the base of the wing, at its posterior edge arising more abruptly from the fuscous band; and the apical dusky portion of the wing is more often connected by fuscous streaks to the transverse band.

In *saxatile* the HIND FEMORA are more distinctly fuscous-fasciate externally, and internally the proximal two fasciae less completely connected; the HIND TIBIAE are a less vivid red, the base is black, the pale annulus usually distinct; while in *scudderi* the base though often sprinkled with fuscous is rarely or never black, the pale annulus is often entirely lacking, and the red is more intense in hue.

Saxatile is much less pubescent: *scudderi* being markedly so, especially along the lower edge of the hind femora.

The COLOR of *saxatile* is black, or brownish fuscous, on an ash-gray ground; of *scudderi* a rusty, often bright red-brown, flecked with darker, the ground color inclining to ochreous, rarely showing white, which is commonly found in *saxatile*.

2.—*S. bolli* vs. *S. aequale scudderi*.

In *bolli* the HEAD is less tumid below; the eyes noticeably larger in proportion; the vertex narrower, more acute, and less advanced; the face in profile less vertical, and less rounded at meeting of costa and vertex.

In *bolli* the PRONOTUM is more nearly rectangular behind; the sides of the posterior process straight instead of excavate; the disk is flat, and much less rugose on prozona; the CARINA is much lower, less arched, equally compressed throughout instead of broadly joined to the disk on posterior half of prozona; the inci-

sion is very nearly vertical and less deeply sunken, the notch usually closed but the two lobes of the carina never overlapping as is often the case in *scudderi*.

In *bolli* the TEGMINA are more obviously fasciate; but the fleckings are less sharply outlined and the colors more suffused.

The WINGS differ markedly in the two species. In *bolli* the fuscous band does not reach the anal angle as in *scudderi;* its margins are less sharply defined; it averages narrower in width, and the subcostal shoot is shorter. In the extended wing the lateral dimension of the yellow disk is less than the antero-posterior, while in *scudderi* they are about equal. The infuscation of the tip is fumose in character: in *scudderi* usually maculose and the spots more or less fenestrate.

In *bolli* the HIND FEMORA are much like those of *scudderi* in the markings of the inner side; but the HIND TIBIAE are very different. In *bolli* these are colored as follows: at base black, followed by a pale annulus, beyond it a fuscous annulus melting into the red of the distal half; the distal fifth is often infumated: while in *scudderi* the entire tibia is coral-red, sometimes showing signs of a pale annulus next to base, the latter sprinkled with fuscous.

The COLOR of *bolli* is more lilaceous in tint, the maculations less sharply outlined and more suffused with the ground-color.

3.—*S. oculatum* vs. *S. aequale scudderi.*

Oculatum may be readily distinguished from *scudderi* by its inferior size, the ♀ of the former about equaling the ♂ of the latter.

In *oculatum* the HEAD is less compressed, especially above; the eyes are much larger proportionally and are more prominent (see fig.); and the antennae are longer in proportion. The facial costa is rather more sulcate, especially in ♂.

The PRONOTUM presents no distinctive characters though in *oculatum* it is rather less compressed and the posterior process rather more acute than in *scudderi*.

In *oculatum* the HIND FEMORA are less distinctly fasciate externally, and internally show a decided difference: in *oculatum* the proximal fuscous band is obsolete ventrally, and the proximal two are not connected; while in *scudderi* the proximal fascia is complete and the proximal two are broadly connected in tibial groove and on inner side, giving the appearance from below of a single very broad fascia. In *oculatum* the HIND TIBIAE seem to be more often annulate with pale basally, and are less vivid in color.

In *oculatum* the pubescence of the hind femora seems to be more highly developed than in *scudderi*, but individuals vary much.

The COLOR of the body as a whole is very similar, but *oculatum* has more of a yellowish cast, while in *scudderi* reddish or rusty predominates. This difference, however, is doubtless due merely to the character of its haunts.

4.—*S. saxatile* vs. *S. bolli.*

In *saxatile* the HEAD is larger and less compressed; the eyes are slightly larger and distinctly more prominent; the vertex broader, less acute, less advanced and more declivent; the face more nearly vertical and more rounded in profile at meeting with vertex.

In *saxatile* the PRONOTUM is less compressed posteriorly, the disk is less angulate on the anterior margin, broader on the metazona, the apex of posterior process less sharply pointed. In *saxatile* the DISK is less flattened; arched mesially in median section on the metazona, and on hinder half of prozona sloping up to form the carina. The CARINA is scarcely as high, much lower on posterior half of metazona, unequally and less developed throughout; while in *bolli* it is equally developed, rising sharply from the flat disk. This is more noticeable in ♂ than in ♀.

In *saxatile* the incision of the principal sulcus is deeper, and the notch open instead of nearly or quite closed.

In *saxatile* the maculations of the TEGMINA have sharper outlines and contrast more with the ground color. The WINGS are more vividly colored, the fuscous band blacker and more sharply defined, reaching the anal angle, while in *bolli* it fades out some distance short of that point. In *saxatile* the subfrontal shoot is longer, reaching about halfway to base of wing; in *bolli* about one third to base. The apical fuscous portion is either maculose or fumose and frequently connected to transverse band; in *bolli* usually fumose and very rarely connected to band. In *saxatile* the lateral and antero-posterior dimensions of the yellow disk of the extended wing are about equal; in *bolli* the antero-posterior exceeds the lateral.

The HIND FEMORA do not differ markedly, the proximal two fuscous bands on the inner side are perhaps more completely connected in *bolli* than in *saxatile*, but considerable variation occurs.

In *saxatile* the HIND TIBIAE, while often showing some slight

infuscation externally distad of the pale annulus, are rarely ringed with fuscous as in *bolli;* this, however, though helpful, is not a safe character upon which to determine the species. I have seen a specimen of *saxatile* which showed there a complete though slight fuscous annulation.

In COLOR *saxatile* presents much more contrast than *bolli*, the markings being blacker and the ground-color paler in hue with more or less white. *Saxatile* lacks the lilaceous tint of *bolli* which may even become bright reddish brown.

5.—*S. oculatum* vs. *S. saxatile.*

Oculatum may be readily distinguished from *saxatile* in several ways:—

The species is smaller, the ♀ about equaling *saxatile* ♂; the eyes are larger and more prominent.

The PRONOTUM offers the best characters. It is very acute posteriorly in *oculatum*, the sides of the posterior process excavate; in *saxatile* very nearly or quite rectangular, the sides straight. In *oculatum* the MEDIAN CARINA is high and arched, especially on metazona, the incision oblique and notch even fenestrate; in *saxatile* low, especially on posterior half of metazona, rather sinuous, the incision nearly vertical, the notch open.

In *oculatum* on the inner side of the HIND FEMORA the proximal two bands are not connected, and the proximal one is obsolete in tibial groove; in *saxatile* these bands are usually broadly connected, appearing from below almost like a single fascia.

Oculatum is much more pubescent, and the color is different, yellowish brown predominating, as compared with blackish fuscous and ash-gray in *saxatile*.

6.—*S. oculatum* vs. *S. bolli.*

Oculatum is smaller in size than *bolli*, the ♀ of *oculatum* about equaling the ♂ of *bolli*.

In *oculatum* the HEAD is much less compressed; the eyes are larger and more prominent; the vertex is much broader, less advanced, and more declivent; the facial costa is broader, and its profile more rounded at meeting with the vertex.

In *oculatum* the PRONOTUM is very acutely angled behind, the MEDIAN CARINA high and arched, less compressed at base on the posterior half of prozona; the incision oblique, the notch even fenestrate; while in *bolli* the pronotum is nearly or quite rectangular behind, the carina is only of moderate height with its

dorsal edge relatively straight, equally compressed throughout, rising abruptly from the flat disk, and the incision nearly or quite vertical.

The WINGS show decided differences. In *oculatum* the fuscous band reaches the anal angle, but stops short of this in *bolli;* the apex of the wing is often deeply infuscated (fumose) in *bolli*, especially the ♂, rarely so in *oculatum* (slightly maculate).

The HIND FEMORA show a difference on the inner side. In *oculatum* the basal fascia is obsolete in tibial groove and is not connected with the next; in *bolli* the proximal two are very broadly connected giving the appearance from below of a single very broad fascia. In *oculatum* the HIND TIBIAE may be slightly infuscated at base but are red beyond, often showing a pale annulus next to base. In *bolli* they are black at base, beyond this a pale annulus followed by fuscous, and on the distal half coral red, sometimes infumated at tip.

And finally the fuscous maculations are more sharply outlined in *oculatum* than in *bolli.*

ON A NEW SPECIES OF AMETRIDA.

BY HARRISON ALLEN.

Ametrida minor sp. nov. Coloration almost white. The third phalanx of the third finger is nearly twice the length of the second. The third phalanx of the fourth finger is a third longer than the second. Much smaller, as a whole, than *A. centurio.* The horizontal plate of the palatal bone is not deficient behind, but extends slightly back of a line which

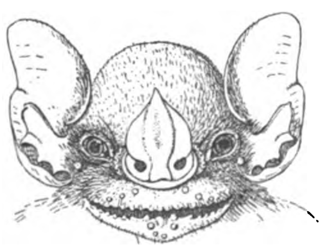


Fig. 1. Ametrida minor H. Allen.

unites the last molars. The posterior nares are remarkably small, being contracted to mere pinhead diameters. The superior incisors do not fill in the space between the canines.

Locality unknown. Type, a male, mature individual in alcohol. Fig. 1. Museum of the Boston society of natural history.

Ametrida (*A. centurio*) was founded by J. E. Gray (Ann. and mag. nat. hist., ser. 1, v. 19, p. 407, 1847), apparently on a single alcoholic specimen from Brazil. The account is short and unsatisfactory. W. Peters (Monatsber. akad. wiss. Berlin, 1866, p. 396) more fully redescribed the genus from a single dried skin (without locality) in the Leyden museum. G. E. Dobson[1] (Cat. Chir. Brit. mus., 1878) gives an extended account of Ametrida, but refers to a single individual from Brazil probably the type specimen. Peters, contrasting Ametrida with Sphaeronycteris (Monatsber. akad. wiss. Berlin, 1882, p. 987) employs characters not used in his first description; one can only assume that additional material had passed under his observation.[2]

Thus the bibliography of the genus is scant. In the long period intervening between 1847 and 1893 but two individuals are mentioned by authors.[3]

The general aspect is that of a species of Stenoderma, but the second metacarpal bone is abruptly bent with a convexity outward. All the measurements tend to be larger than *A. centurio*. The third phalanx of the third digit is little more than half the length of the second. The second phalanx of the fourth digit is longer than the first.

[1] Dobson states that the palatal bone in *Ametrida centurio* is deficient behind, and since he is in doubt as to the propriety of separating Ametrida from Stenoderma, it is probable that this deficiency is similar to that in Stenoderma and amounts to a deep sinuosity of the posterior palatal border. In the Leyden specimen, the parts were said to be mutilated; yet Peters in his second paper states that the border is scarcely cut out.

[2] Sphaeronycteris resembles Ametrida in the general shape of the skull, in the number of teeth, in the rounded head, in the general shape of the ears and tongue, the manner of attachment of the wing membrane to base of toes, in the short calcar, in the deeply incised interfem, and in the skin-formations about the nose-leaf. But the nose-leaf of itself and the physiognomy are quite distinct. The anterior temporal crest is extraordinarily widened; the nose-leaf is surrounded above, and the plicae of the face suggest a disposition of parts as in *A. centurio*. The tragus is more sinuate on the outer border. The incisive foramen is very small; the posterior border of the palate reaches the level of the second molar; the breadth of the basicranium between the cochleae is as wide as the exposed portion of the cochleae themselves. The coronoid process of the lower jaw is higher than in Ametrida.

[3] Since our knowledge of the genus is as yet imperfect, I have thought it best to give the characters of *Ametrida centurio* as gleaned from Peters. It is as follows: posterior palatal border scarcely incised; basicranium very small, not so wide as the cochlear exposure; anterior temporal crest marked; interfemoral membrane incised; general coloration of the fur brown.

The characters of the head, ears, nose-leaf, and even the gland-like swelling on the front of the thorax, are as in *A. centurio*. The warts on the lower lip are six in number instead of seven as in that species. In comparison with the figure given by Dobson they are not well defined. The markings of the wing membranes are as in other species of Stenodermatidae, excepting that the mesopatagium is furnished with eleven long, nearly vertically disposed muscle-lines which converge to a single point near the forearm.

The terminal cartilages are filiform. The pigment is absent in the first and second digital interspaces.

The gland-mass at the other side of the nose-leaf is raised on a skin fold as in Ectophylla. The glands, three in number, are lodged well up on the face and occupy a groove between the eye and the nose-leaf.

Teeth. Peters in his description of *Ametrida centurio* describes a small "basal cusp" on the maxillary central incisor, and a bilobed minute lateral incisor; the lower premolars are not of the same form and size, the second being smaller than the first. These characters are not found in *A. minor*, in which species the superior lateral incisor is nearly half the length of the central. Dobson gives a description to which the teeth of the new species conform for the most part, but I find the intervals between the maxillary centrals too great to accept the statement that the teeth fill up by their bases the wide space between the canines. I infer that the London and Leyden specimens are not so much alike as are the London and the Boston examples, so far as the characters of the teeth are concerned.

Rugae two in number; the rest of the hard palate being occupied with minute mammilations as in Sphaeronycteris. Fur above including the head is of a dull white; the hair is long, the extreme tip and base having a delicate shade of brown. Beneath, a conspicuous patch pure white in color lies on the ventral aspect of each shoulder. A covering of short hair is seen on the wing membrane extending from the trunk to the distal third of the humerus and almost to the knee. This distribution is noteworthy from the fact that it is not distinctive from that of the back of the trunk, but the hair in the region just named extends upon that of the wing membrane so that no limitation between the trunk and the membrane can be detected. The fleshy part of the forearm

is sparsely furred. The rest of the membrane is naked except the inferior border of the wing membrane where a delicate fringe of hair is seen. The remainder of the ventral aspect is much darker (with tawny brownish shades prevailing) than on the back; the hair toward the side of the trunk (mammary line) is much longer and deeper in shade than elsewhere. The hair is unicolored. It extends in an abruptly defined, sparse layer on the wing membrane as far as the end of the fleshy part of the forearm and to the wing membrane just beneath it and thence obliquely downward and inward to the knee.

The dorsal aspect of the interfemoral membrane, the thighs, and legs are covered with hair. This is sparse over the limbs, but better developed over the membrane, especially at the middle third.[1] The under surface is nearly naked but the thighs are thickly furred in a manner unusual in the family. The abruptly bent metacarpal bone of the second digit is the most striking character in the skeleton. The penis is not pendant but directed upward parallel to the abdomen. The prepuce is half withdrawn from a subconical glans.

MEASUREMENTS.

		A. minor	*A. centurio*[2]
Head and trunk		35 mm.	40 mm.
Head		13	15
Ear, height of		11	
Tragus		4	4
Nose-leaf height		7	
" width, under part		5	
Length of trunk		26	
Forearm		24	32
1st digit	thumb	9	
	metacarpal	3	9
	phalanx	6	
2d digit	metacarpal	14	
	phalanx	6	
3d digit	metacarpal	23	29
	1st phalanx	8	11
	2d "	13	17
	3d "	7	14

[1] The Leyden specimen is stated by Peters to be sparsely haired only on the interfemoral membrane.

[2] Calculated from the English scale as given by Dobson.

4th digit	metacarpal	20	26
	1st phalanx	9	10
	2d "	12	7
5th digit	metacarpal	21	27
	1st phalanx	8	11
	2d "	10	14
Tibia		13	16
Calcar		4	5
Foot		9	8

Since the above diagnosis was written out, I have made a detailed study of the skull. The division into metacephalic and mesocephalic portions is well defined, but the procephalic is absent. The brain case is greatly expanded, and the face is correspondingly narrowed.

View from in front (*norma frontalis*, fig. 2.) The temporal

FIG. 2.

crest is faintly defined at anterior third of the sagitta. Posterior line is absent; the anterior line is trenchant and extends well down to the inner wall of the orbit where it is continuous with the orbital crest. The ridge at the position of the postorbital process as seen in some genera, as those of the Emballanuridae and in *Pteropus leucocephalus*, is bolder than elsewhere but is directed upward and outward rather than downward and outward. The two ridges diverge in such wise as to define a shield-like space on the frontal bone. The anterior nasal aperture is large, well carried up toward the orbits, thus showing the presence of small, broad nasal bones. The zygomatic arches are boldly expanded laterally.

The sides of the skull (*norma lateralis*, fig. 3) show the pos-

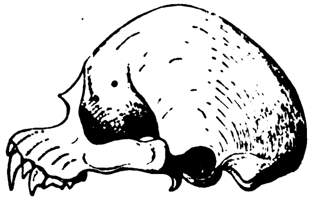


Fig. 3.

terior half of the brain case sloping markedly toward the occiput, the superior semicircular line of which lies well down toward the base; the bone below it inclining slightly toward the foramen magnum as in the pteropine bats. The anterior half of the brain case is convex, and the curve ends abruptly at the level of the ethmoidal foramen.

The nasal bones project at the anterior nasal aperture; the horizontal and ascending limb of the lateral borders of this aperture are about equal. The ascending limb is slightly oblique and concave. The upper border of the wide zygoma is rugose at the position of the ascending process. The alveolar border of the maxillary is nowhere horizontal but inclined upward and forward from second molar and upward and backward for the short distance answering to this tooth.

The base of the skull (*norma basilaris*, fig. 4) exhibits a large

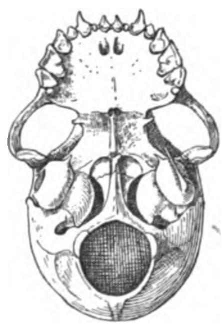


Fig. 4.

circular foramen magnum, a narrow oblique basilar process with deep lateral depressions. Tympanic bones small, half covering

the petrous bone but in firm contact therewith. Zygomatic arches expanded and acutely bent. Pterygoid fossa not distinguishable from the mesopterygoid; a median ridge lies directly back of the exceedingly minute posterior nares. The hard palate wider than long and faintly incised between the scarcely produced palatines. The lower jaw possesses a high acute coronoid process. The condyloid process carried back slightly beyond the line of the angle which is deflected outward.

MEASUREMENTS OF THE SKULL.

Length	15 mm.
Greatest width	5
Length of face from fronto-nasal junction to the alveolar point	4.50
Bimalar breadth	10
Length of hard palate	5
Width of hard palate at the last molars	4
Glenoido-alveolar length	6.02

General Meeting, March 7, 1894.

President W. H. Niles in the chair. Twenty-five persons present.

Mr. F. P. Gulliver discussed the Newtonville sand-plain. (See Journal of geology, v. 1, p. 803–812.)

Mr. J. B. Woodworth read a paper on some typical eskers of southern New England. (See p. 197–220.)

ON THE DISTRIBUTION OF EARTHQUAKES IN THE UNITED STATES SINCE THE CLOSE OF THE GLACIAL PERIOD.

BY N. S. SHALER.[1]

In some studies which I have recently made in the distribution of earthquake shocks it became evident that it was desirable to ascertain what proof could be found which might serve to show the

[1] Read January 17, 1894.

distribution of these shocks in times anterior to the brief period of which we have any historical record. I have already made reference to the results of this inquiry in an article published in Scribner's magazine for March, 1887, entitled "The stability of the earth." In that paper, however, it was undesirable to treat the subject in any other than a very brief way. I propose in the following pages to set forth the methods by which we may obtain some knowledge of earthquake phenomena in the earliest stages of the present geological period with incidental reference to such disturbances in former geological ages.

There are two ways in which violent earthquake shocks produce effects which may be observed long after the time when the shocks occurred. When these shocks take place beneath the sea-floor, they produce, as is well known, a sudden elevation of the water in the form of a great disc immediately over the point where the disturbance takes place. From this seismic vertical the elevation of the water is propagated in every direction in the form of a great wave, which though low is very wide. Approaching the shore, this wave is heaped up on its front through the fact that the shoals retard the movement of the undulation where it comes into shallow water, and so causes the following portion of the wave to crowd against the preceding portion of the ridge. On the western coast of South America and elsewhere along the Pacific shores, these waves frequently attain a height of thirty or more feet, and owing to their great momentum sweep far up the shore producing on the land effects which in certain cases may long remain evident. The action of a powerful earthquake shock is recorded in another manner. It overturns all instable bodies, such as delicately poised masses of stone, those natural obelisks which are frequently formed by the processes of rock decay, or boulders which are delicately poised in instable positions. By carefully observing the regions where such natural seismometers remain unshaken we may receive important evidence as to the recent distribution of these disturbances.

Considering first the effects of ocean movements induced by earthquakes, we find that where they strike the shore, they exert a very great amount of energy which causes an overturning of any poised bodies which may come within the limits of their more vigorous action. An inundation will also operate to efface any delicate topography cast in frail material such as sand, which may

exist along the shore, destroying or modifying the relief in a manner which can be interpreted long after the occurrence of the catastrophe. It appears to me possible by a careful study of most shores to determine whether they have recently been subject to inundations of this nature. Thus far I have been able to apply the method of inquiry only to the coast of the United States between Eastport and Key West. I shall give the general results of the inquiry on this extensive shore section in order at once to show the method in which it can be used and the evidence concerning earthquake shocks beneath the Atlantic floor during the period which has elapsed since the eastern coast line of the United States came to its present position.

Between Eastport and the mouth of the Hudson, the evidence concerning these oceanic waves, though complicated, is of a very legible nature. On this shore the facts which afford us information are those which owe their existence to glacial action. Along the rocky part of this coast, we have a great number of poised boulders, erratics which were left in their position by the melting away of the glacier, and which lie in attitudes where either a considerable shock occurring beneath them or the incoming of a great wave would inevitably lead to their displacement. In my examination of this shore, the greater portion of which I have actually seen either on foot or from a small boat, I have found many hundred boulders delicately poised in positions where the blow of a great wave would lead to their overturning. We often find the boulders slightly supported on the margins of steep declivities just above the present range of the waves so that anything but the most trifling disturbance would cause them to be precipitated down the slope. Although in some instances it is possible to suppose that vegetation, the roots of trees and their stems, may at one time have served in a measure to fix them in their resting places, there are many other cases in which we can affirm that the instability of their attitude must have continued for all the time since the shore came to its present level.

At other points along these rocky shores, especially on the coast of Maine, as on Baker's Island south of Mt. Desert, the ocean waves have heaped up a sea-wall composed of angular fragments torn from the jointed crystalline rocks. An inspection of the stones composing these walls shows that most of the fragments have long been in their present positions, and also that they

are disposed just as ordinary storm waves would place them. A powerful blow of an earthquake wave would carry much of this material beyond the position in which it lies and distribute it in a manner which would be very suggestive to the observer.

At many points along the New England coast the hard rocks have been eroded by the sea in such a fashion that considerable pinnacles, in a very instable state, have been left. Such projections are particularly conspicuous in the region north of New England along the shores of the Gulf of St. Lawrence. In that district they afford evidence of immunity from ordinary earthquake shocks, but they cannot be taken as affording proof that waves from the sea produced by earthquakes have not swept along the Atlantic coast, for the reason that such waves would not be likely to effectively penetrate through the narrow passages which lead from this basin to the open sea. I therefore make no further reference to them in this connection.

A large part of the New England shore, from Portland to New York, exhibits other features derived also from glacial action which afford a test of these sudden marine inundations. These are the well-known kames: those delicately molded heaps of drift composed of sand and gravel brought to their instable attitudes by the action of currents. Nearly the whole coast of Massachusetts and the shore of Long Island, as well as the southern portion of Connecticut and Rhode Island, are bordered by this kame belt. At many points, indeed, we may say along the greater portion of this shore, the upper level of these delicately molded sands lies next the shore at the height of not more than from twenty to thirty feet above mean tide. On the southern coast of Massachusetts and Rhode Island there are extensive belts of this nature which have their upper surfaces within ten or fifteen feet of mid tide line. No one who is acquainted with this kame district would for a moment assume that a great wave, such as those which have swept the coast of South America and other countries, has ever rolled over them. Such a catastrophe would lead to the destruction of these frail features or at least to a profound modification of their forms. The slopes of these undulating surfaces are often very steep. At many points the declivities have the irregular conical hollows at angles of from twenty to twenty-five degrees with the horizon. Although these slopes have been somewhat degraded by atmos-

pheric action, an inspection of numerous cross sections has shown me that the material which fills the basins is invariably fine sand which has been gradually accumulated and not of a nature which we should find if it had been brought into its position by the tumultuous action of a great invading wave. It is not too much to say that any one wave such as has ravaged parts of the Pacific shore would have left an ineffaceable mark on this delicate topography. I therefore conclude that, since the New England coast assumed its present level sometime after the close of the glacial period, the region of the North Atlantic between America and Europe has been exempt from shocks having the magnitude of those which have prevailed in parts of the Pacific Ocean as well as in the more southern parts of the Atlantic.

South of New Jersey and thence to southern Florida the evidence is of a less distinct nature but to the same effect as that which we find in New England. The southern sand-plain from New Jersey to Cape Florida exhibits gentle undulations apparently of the same type, though less accented, as is shown in the kame terraces of New England; but these reliefs are so slight, rarely exceeding 10 ft. in a square mile, that we cannot make quite sure that they have not been subject to the inundations caused by earthquakes. There is, however, another feature of this district, viz., the barrier beaches of sand, which throws some light on our problem. From Cape Henry at the mouth of the Chesapeake southwardly to Cape Florida, there is an almost continuous barrier of wave-tossed sand more or less crowned and backed by dunes. This beach wall incloses a series of lagoons so nearly connected that in the wet season a canoe can, with a few trifling portages, be taken along the length of this extended shore. As may well be imagined, this feature affords us certain tests as to the invasion of great earthquake waves. An inundation of this nature sweeping over a sand barrier would in good part efface it. The lagoons behind the barrier suddenly filled with water would on the surgence of the waves burst through the barrier in their escape to the sea. Although such openings would inevitably in a short time be closed by the movements of the sands, the evidence of the former existence of the inlet would be plainly manifest for some thousand years. I have examined a good many hundred miles of these barricaded waters and find no evidence of such accidents.

Moreover the interior margin of the sea-wall is generally covered by an extensive system of low dunes which were evidently slowly accumulated. These dunes have their characteristic topography which would have been effaced by any vigorous incursion of the sea.

Although I regard the evidence afforded by the coast-line south of New York as less determinative than that obtained in New England, it seems to me eminently probable that the whole coast of the United States from Eastport to Cape Florida has been for a considerable period, perhaps for ten thousand years or more, exempt from the action of any great marine waves formed by earthquakes. My observations on the shore lands of Nova Scotia and Cape Breton, though less carefully made, incline me to make the same statement concerning that region. Similar though less connected observations on the western shores of Great Britain and northern France lead me in a general way to the same conclusions. They are to the effect that the North Atlantic has been exempt from this class of cataclysms since its lands came to their present attitudes with reference to the sea.

It appears to me desirable to extend this system of observations to other portions of the ocean border. To accomplish this task, the observer should first make himself acquainted with the facts as exhibited along our New England coast. He should then study the part of South American shore which has been most subject to these inundations. A careful comparison of the topographic details in these two sections would carry the inquiry to its conclusion.

I now turn to the evidence concerning the violence of earthquake shocks as indicated by topographic monuments on the land areas. The question we have hitherto considered does not concern the energy of the shocks at the point where they occur beneath the sea, of which we can have no evidence, but the effect of the waves propagated through the sea for great distances by the seismic impulse. Hereafter our question will be as to the energy of the movement in the earth itself as indicated by the details of the surface. As a preparation for this inquiry I have carefully observed the topographic features in the part of Italy where earthquakes of great violence frequently occur. I have endeavored to apply the considerations derived from such study in regions of great seismic activity to other districts in which

we have no historic evidence of great shocks. As I am not aware that any other observer has undertaken a study of this nature, I have been compelled to devise my own means of inquiry. The basis of experience is not sufficiently great for assured conclusions, but I venture to hope that others who are better fitted for the task may undertake to extend these considerations.

The influence of an earthquake shock on topographic features has often been described. Where the shock is of moderate energy, even though it prove destructive to weak architecture, there is generally little effect on the earth's surface which can be observed after any considerable interval of time. The simplest and most general topographic effect exercised by earthquakes of moderate intensity is found in the action they produce on extensive alluvial plains or other deposits in which a considerable amount of chemical change takes place in porous strata lying near the surface. Thus the earthquake of Charleston, S. C., though a shock of no great violence, exhibited in a sufficient manner the peculiar influences of such convulsions on the above-described kinds of rocks. In such alluvial or other porous superficial deposit, the rainwater penetrating through the humus layer finds its way downward to a considerable distance. It exercises a certain solvent action tending in a limited way to create cavities beneath this surface and to increase the storage of water within a few feet of the air. The penetration of this water and the processes of metamorphism due to other causes generate a considerable amount of gas, carbon dioxide and other gases, of decomposition, which seek to escape but not with sufficient energy to overcome the resistance of the overlying matter. Any considerable earthquake tremor of the area releases more or less of this gas which impels a portion of the water along joint planes and through other lines of weakness to the surface, where it breaks forth from crevices situated on such lines of fractures. Thus in the Charleston earthquake, as before remarked, though one of relatively slight energy, a large part of the region affected by the movement poured forth its subterranean waters from thousands of openings. Over a large part of the region near Somerville and at other points in the shaken district, these pits were extremely numerous and they will long remain as distinct indications of the disturbance. Some of them are sufficiently

large to endure for centuries. Their deposits in the form of fine micaceous and other sands laid down in a stratified manner on the surface about the basin are likely to remain, if undisturbed by human agency, for many thousands of years as evidence of the disturbance which produced them. Similar outbreaks of water on a more extensive scale marked the action of the great shocks of the New Madrid earthquake which occurred between 1811 and 1813. They have been observed in almost all regions where considerable earthquakes have occurred in districts where the surface was approximately level and to a considerable depth underlaid by incoherent materials.

Although it may be possible by close study to determine whether earthquakes have occurred within a few thousand years in a region such as those above noted, the observation will have to take account of very inconsiderable phenomena, and I therefore fear that it will not be possible to make much use of this indication in determining the recent seismic history of a country. It is, however, worth while for the observer to bear the matter in mind. I am inclined to think that a careful study of the alluvial country in our southern states may show faint traces of former shocks through the preservation of some of these water craters made in former centuries.

The next important topographic index of earthquake shocks is found in the soil covering which forms on steep slopes where there is a considerable surface lying at angles of more than 25°. The condition of this soil covering will often give an important clue to the seismic history of the field. If the soil coating accumulated on this slope is of some thickness and continuity, we may be sure that the regions have not been subject to powerful shocks within the period demanded for the accumulation of the deposit. As long as such a slope remains unshaken, the decay of the rock in the subsoil and perhaps the constant falling of debris from the overhanging cliffs, the fragments being caught and fixed in the mass of vegetation, will continue the process of accumulating the soil, but a vigorous movement of the region in the successive to and fro motion of an earthquake will certainly urge the mass downwards towards the base in the form of a landslide. Such landslides are conspicuous phenomena in all great shocks which occur in countries having mountainous slopes. Thus in the earthquake of 1692 on the island of Jamaica a large part of the

upper slopes of the Blue Mountains had their soils along with the forests which covered them precipitated into the valleys below. Judging by this test we may affirm that a large part of the area included within the Appalachian district of North America has not been within the last few thousand years shaken by great earthquakes. The condition of the soils lying on steep slopes in this region excludes the hypothesis of violent seismic action.

The most important and on some accounts the best preserved indices of earthquake movements in any inland district are found where the topographic conditions due to the action of erosion have produced more or less numerous detached columns of rock, the needles and pillars which are so often found on the front of a great escarpment. The effect of an earthquake shock on the more instable of these natural obelisks is often very great. The process of decay generally brings these columns into a state of extreme instability before they give way under the influence of their own weight. In an effort to establish conclusions on these features, the observer must take pains to note whether the instability be real or not, for the eye may often be deceived and misjudge the resistance which a mass may oppose to disrupting forces. With a little care, however, it is easily ascertained whether or not a detached mass is a good seismometer. Thus in the Appalachian Mountains south of the glacial belt, there are many districts where we can prove that a shock of any considerable violence would necessarily overturn scores of isolated fragments which have evidently occupied a very instable position for some thousands of years. They afford substantially the same evidence as to immunity from earthquakes which the frail gothic spires of northern Europe give for the centuries since their erection. On the banks of the Kentucky River, at various points in the Cumberland Mountains and northward to central Pennsylvania, I have observed natural obelisks which seem to me to afford an irrefragable evidence that intense earthquakes have not affected that region for some thousands of years. So far as I have been able to observe the regions of known seismic activity in southern Europe, I have failed to find any such detached masses in a similar instable condition.

Evidence of the same general nature, though on the whole less conclusive, may be found in any of the numerous caverns of this country which contain extensive masses of stalactite. These ac-

cretions may often be observed in positions where they are no longer growing, in chambers into which the waters long failed to enter. They are sometimes found with thick deposits of cavern dust lying beneath their dependent masses, showing clearly that the waters which formed them have long since ceased to contribute to their masses. The great length of these stalactites, taken in connection with their ponderous weight and the ease with which they are riven with a strain, makes them excellent indications as to the absence of seismic action. There are many caverns in Kentucky, Virginia, and elsewhere, which contain in their stalactites evidence that the earth about them has never been violently shaken since the caves were formed. Were it not for the fact that we cannot determine in any case, with near approximation to truth, the length of time which has elapsed during which these masses have escaped seismic action, they would be valuable data for reckoning the immunity of the region from earthquakes. As it is, they can be taken only as tolerably general indices of a long-continued exemption from great shocks. In none of the scores of American caverns which I have explored are fallen stalactites of large size at all common, and in all of those which I have had a chance to examine it seems likely that the falling was due to a giving away of the rock to which they were attached through gravitative action alone. In the caverns of Kentucky, Tennessee, and Virginia, we find tolerably clear indications that for a very considerable time, perhaps for some thousands of years, there has been no movement sufficiently violent to give these great masses anything more than the slightest motion. I am of the opinion that a shock having a horizontal movement as great as that which occurred at Charleston would bring a large part of these structures from their places on the ceiling to the floors of the caverns.

It is hardly necessary to state that these several evidences of exemption from serious earthquake shocks can be found in but few parts of any country. It is only where we have a topography characterized by strong reliefs or where caverns with extensive stalactites occur that any determination appears possible. Nevertheless from existing scanty data, it appears to me that we may affirm an exemption from earthquakes of many extended districts in North America. The whole of the Appalachian belt gives us one or the other of the proofs which contraindicate the action of earthquakes of more than moderate severity since

the close of the glacial period. In the northern section, we have numerous poised boulders often occupying positions where they have never been supported by forest trees. Sometimes a large boulder bears a small one riding upon the top of it, affording a natural seismometer of considerable sensitiveness. In other cases, as before described in our consideration of sea-waves due to earthquakes, these boulders are poised on the borders of steep-faced hollows into which they would inevitably have been precipitated by any considerable movement of their bases. It is often possible to start these fragments down their slopes even where they have the weight of tons, with a very slight amount of displacing force. South of the glacial belt, wherever the escarpments are of a nature to yield detached masses in the process of decay, we almost always find them and often in an extremely instable condition. Natural bridges, over-hanging precipices, tottering on their fall and occasionally giving away under the influence of the atmosphere, caverns charged with stalactites, very steep slopes with a uniform covering of soil, all point to the same conclusion, viz., that a large part of this Appalachian region has long been exempt from devastating shocks. In a similar way, the region about our great lakes and a large part of the Cordilleran district north of Mexico afford indications of long-continued repose. Such regions as the Saxon-Switzerland in Europe, and generally the topographic character of the region north of the Alps, point to the same conclusion. On the other hand the whole of the Italian peninsula, so far as I have explored it, seems to indicate, by the absence of soil on steep slopes and the lack of instable erosion columns in front of the escarpments, the action of powerful earthquake shocks.

It appears to me that the foregoing suggestions as to the evidences of former earthquake activity beneath the seas and upon the land surfaces may fairly be made a matter of deliberate inquiry. It is worth our while to know the seismic history of a district, not only on account of the scientific questions involved, but also because earthquakes are at present by far the most unforeseeable of all calamities which beset life. If we could in any way determine the earthquake record of a country for the period say of ten thousand years in the past, we should be in a better position to predict the chance of recurrence of shocks within the given field.

General Meeting, March 21, 1894.

Vice-President B. Joy Jeffries in the chair. Forty-one persons present.

Prof. H. C. Ernst read a paper on phagocytosis.

THE GEOGRAPHICAL DEVELOPMENT OF ALLUVIAL RIVER TERRACES.

BY R. E. DODGE.[1]

Contents.

Introduction.

The following account of alluvial river terraces is a summary of the work I did last year in the advanced course of physical geography at Harvard University, under the guidance of Prof. W. M. Davis, to whom I owe many suggestions and criticisms.

Description of a River Terrace.

A river terrace always consists of a plain and an accompanying escarpment. The terrace plain is approximately horizontal and usually slopes both with the grade of the stream and away from

[1] Read December 6, 1893.

the river bed which it faces. On the side toward the stream the plain is bounded by an escarpment, the two together making the terrace: the opposite side of the plain is usually bounded by more elevated land, either an older and higher terrace or the true valley wall. Terrace plains represent approximately the level of the stream at the time of their formation, while the height of the escarpment shows the depth to which the river cut before forming another plain.

Classification of Terraces.

The topographic form sketched above includes all river terraces, divisible, however, according to their origin into two great classes; terraces of planation, formed in the solid terrane of the region; and those formed in the loose alluvial deposits of the river valley, which are termed alluvial terraces. I shall devote my attention to the latter class only.

Alluvial Terraces and Alluvial Plains.

Alluvial terraces are formed by streams cutting down into the loose waste accumulated in their valleys, usually in the form of alluvial plains. Thus alluvial terraces and alluvial plains are very intimately associated, and a consideration of the former necessarily includes a consideration of the latter. An alluvial plain represents one of the forms assumed by the waste of the land on its way to the sea; an alluvial terrace is then a secondary form imposed on the waste of the land under certain conditions which I shall consider later. Among other characteristic forms in addition to alluvial plains may be mentioned alluvial fans, talus slopes, etc. Any one of these considered in its relation to the river would furnish interesting matter for a separate paper.

An alluvial terrace is formed in the loose alluvial materials of a river valley as the result of three actions which occur in the following order; first, an initial valley is cut in a land mass; secondly, that valley is at least partially filled with waste; and

lastly, the waste is in part removed in such a manner as to leave remnants of the filling, as terraces, on the sides of the valley. A river valley begins to be filled up, or aggraded, whenever the load furnished to the stream for transportation becomes greater than the carrying power of the river. If at any time afterwards the relation of these two is so changed that the carrying power is more than sufficient to transport the waste furnished it, the stream will begin to remove the filling previously deposited in the valley.

The amount of waste furnished to a stream depends either on the size of the area undergoing destruction, or on the rate of wasting, or on both. The carrying power of the stream depends on the grade of the stream bed, upon the volume of the stream, and upon the pressure under which the stream is running; and increases or decreases with corresponding changes in any of the factors. The effect of decrease of pressure is particularly noticeable in subglacial streams, where it very frequently happens that a load that is easily carried while the stream has its channel hemmed in beneath the ice, becomes too heavy for transportation as soon as the stream reaches the open air and ceases to be confined by the ice.

In any aggrading stream the waste forms an alluvial plain which becomes a terrace plain when, on ceasing to aggrade, the river again begins to degrade its valley. We know that all alluvial plains customarily slope gently with the grade of the stream and away from the bed, as a consequence of the method of their formation. Hence we can easily see why a terrace plain, which is formed from an alluvial plain, should also normally slope in these two directions. The escarpment left by the stream, as it cuts down into its valley filling, forms the terrace escarpment, and the terrace plain plus the escarpment completes the terrace. Alluvial terraces are thus seen to be the result of both constructive and destructive processes, and indicate a period of aggradation followed by one of degradation, on the part of the stream with which they are associated.

Having now noted in a general way the conditions under which alluvial terraces are formed, I will explain more particularly the relation of such terraces to the rivers that have formed them.

Geographical Cycle and Development of a Normal River.

As all forms assumed by waste in river valleys are intimately associated with the geographic development of the accompanying river, I will now briefly describe the development of a river system and show the connection of alluvial terraces to some normal period of a river's life.

The simplest conceivable river is one developed naturally on a rising coastal plain or old lake bottom, now for some reason revealed. Such a river is called a constructional river, for its grade and course depend on the constructional slope of the new land. As has been described by Professor Davis,[1] a constructional stream would at once begin to develop a valley in the plain on which it is formed, in a manner to be described later on. If the land mass of which the plain were a part should continue stationary, the river would in the course of time reduce that land to the level of the sea, or to use a better term, to base-level. The time required to produce this effect is called a geographical cycle. It is very doubtful, however, if any continent has ever remained stationary long enough for such a cycle to be completed, yet still the cycle is a possible one. A river developed in such a simple cycle may well be taken as a type and called a normal river, and the topography resulting from the action of a normal river would be simple because it would be formed in a single cycle. I will now trace briefly the history of such a normal river, following the stream from its birth on the constructional plain to its extreme old age when the constructional plain has been reduced to base-level.

The first work of infancy of a river on a constructional plain would be to sink its channel into the rocks over which it flowed, beginning in its lower portion first. The river would thus gain an increased velocity on account of the greater grade and be able to work more rapidly. It would then lengthen headwards by slowly gnawing backwards into the rocks of that region and would widen its channel by wearing laterally. The wasting effect of the atmosphere would assist in the widening of the valley and in decreasing the slope of the valley sides as the walls

[1] The rivers and valleys of Pennsylvania: Nat. geog. mag., v. 1, no. 3.

were worn farther and farther from the stream bed. At the same time tributary streams would develop in the minor side depressions of the valley and would add both their volume and load to the main stream. As the amount of surface furnishing waste to the stream gradually increased, the load would become greater and greater until finally it exceeded the carrying power of the river. The waste would then be deposited in an alluvial plain, and the river would have passed from its period of infancy, when its work is only destructive, to that of adolescence when it does constructive as well as destructive work.

During adolescence the river would continue to dissect the constructional plain, in the manner just described, until finally nothing would remain as a witness of the original plain except narrow divides which in places would rise to the level of their former elevation, and by their evenness would attest to the previous existence of a connected plain of considerable extent. When the river has dissected its plain to such an extent as this, it is said to have attained maturity. At maturity there would be the greatest diversity of topography in the region, and the river would be doing its most effective work, for there would be the greatest possible amount of surface exposed to erosion and the greatest facility for transportation. As the divides began to disappear in the later maturity of the river, the relief would gradually become less and less intense. The river would at the same time become enfeebled as its grade decreased and would do its work more slowly, until finally the whole region would be almost reduced to the level of the flood plain. The river has then reached old age.

If, however, the cycle of denudation should be interrupted by the elevation or depression of the land, a new cycle would be inaugurated. If the land should rise, the rivers would be revived and would again begin to cut down their channels; if it should sink, the ocean waters would advance into the lower courses of the rivers, forming estuaries, and the rivers would be said to be drowned. As we have called the topography developed in one cycle simple, we may well call that developed in more than one cycle composite.

If then alluvial river terraces should depend entirely for their formation on the development of a river system, we might expect

to find in a terraced valley, either simple or composite terraces, according as the terraces were formed by the river in one uninterrupted geographic cycle or in more than one cycle. But alluvial terraces are formed by other processes than those depending solely upon the development of the river, and as such terraces are often not clearly traceable to one cause, they may well be called complex or involved terraces. In each of these classes there are several subdivisions, which I shall consider later. For instance, among simple terraces we may have normal terraces, due to the normal development of a river; subnormal terraces, due to slight but not abnormal variations in the development of the river; and accidental terraces, due to accidental variations in development. I will consider these in detail.

NORMAL ALLUVIAL TERRACES.

During maturity a river would wear down its whole drainage area nearly to base-level, so that by the beginning of old age its load would in the majority of cases be in excess of its carrying power, due to decreased grade, and it would necessarily even aggrade its valley forming an alluvial plain. Afterwards, to quote Professor Davis[1], "In the later and quieter old age of a river system the waste of the land yielded slowly by reason of the diminishing slopes of the valley sides, then the headwaters deliver less detritus to the main channel, which, thus relieved, turns to the postponed task of carrying away its former excess of load to the sea, and cuts terraces in its flood plain preparatory to carrying it away." At first it would appear that such would be the work of the river in its old age. A more careful consideration, however, would seem to show that terraces would not be formed in old age on account of this very quietness and the slowness of the work at that period of that river's history. The cutting and wasting would then be so extremely slow and evenly balanced that the river could not sink deep enough into its alluvial deposits to form a terrace. If, however, such a terrace could be formed by a river, it would be the simplest and most natural terrace we could possibly have, according to a classification of terraces based on the

[1] Nat. geog. mag., v. 1, p. 205.

development of rivers. It might be objected, in view of what is said above, that such a terrace could have no value as the type of normal terraces; but this criticism does not really weaken the classification as nothing is really built up from it, and also it is just possible that such a terrace may be formed under certain conditions; and it has a decided value for comparative purposes.

Another way in which a normal alluvial terrace might be formed is as follows: suppose that a stream whose load is slightly in excess of the carrying power acquire by capture the headwater portions of another stream. In the district thus acquired, as in the headwaters of all streams, there would be a greater excess of carrying power over load than in any other part of the stream, consequently the capturing stream would probably have its carrying power greatly increased without any corresponding increase in load, and the stream would probably begin to cut into any previously deposited alluvial plain and terrace it.

A third process by which a normal alluvial terrace might be produced would be where a stream which had been working mostly in soft rocks cut down into harder rocks underneath the softer ones. The effect of the difference of hardness in the two beds, or sets of beds, would be a decrease in the load furnished to the stream in a given time, and consequently a decrease in the amount of work which the stream would have to do in order to maintain an unobstructed course. Hence, without any increase in volume the stream might be able to terrace an alluvial plain formed while attacking soft rocks.

We will now pass from terrace-making processes that necessarily occur in any river's history to certain ones which would not necessarily occur in the development of a river, but which, if they did occur, would not be abnormal. Terraces developed by such action may be called subnormal terraces.

Subnormal Alluvial Terraces.

A subnormal terrace might be due to certain climatic changes in the basin drained by the river. Suppose for instance that the amount of annual precipitation in a region should begin to decrease, and we know it has decreased in recent times in certain

portions of the western part of the United States, then the streams of the region would have a slightly decreased volume on account of dessication and being furnished with a constantly decreasing load from the valley sides, would find their carrying power still ahead of the work supplied to them. Therefore they would begin to incise their channels in the alluvial filling dropped during a previous time of greater precipitation. Terraces might thus be formed when the rivers deserted their old flood plain levels. Such terraces have been described by Drew[1] from the rivers of the Himalayas. It may seem at first that it is not legitimate to consider that climatic changes of such magnitude would take place during one cycle of a river's growth; yet the knowledge that Lake Bonneville has been several times filled and emptied during the present incomplete geographical cycle shows us that such climatic oscillations are perfectly natural in the history of a river. The infrequency of such occurrences, however, makes it advisable to consider terraces due to this cause subnormal rather than normal.

A second way in which a subnormal terrace might be formed by a river is as follows: suppose that a growing talus slope, alluvial cone, or a land slide, all of which are perfectly normal features of a river's development, should build a barrier across a stream, damming it back into a lake. Such a barrier would act as an important control on the work of the river as the temporary base-level of the country up stream would be the level of the barrier as long as that barrier existed. Consequently the stream would lose much of its carrying power as it approached the level of the barrier and would deposit much of its load in the temporary lake formed back of the dam. When in the course of time the river should succeed in cutting down through the barrier, it would again acquire a greater gradient and would thus be able to carry a greater load with a given volume. It would therefore cease to deposit detritus above the barrier and would begin to cut its channel down into the alluvial deposits already dropped there, and in so doing might possibly leave terraces.

Furthermore the formation of a barrier might have an important effect on the down stream portion of the river, for it might

[1] Alluvial and lacustrine deposits and glacial records of the upper Indus basin. Quart. journ. geol. soc. Lond., v. 29, p. 441–471, 1873.

greatly diminish the amount of load furnished to that section of the river, so that the relatively greater carrying power acquired by the filtering of the stream by the lake would be expended in removing such alluvial deposits as might have been previously dropped in the lower reaches of the river. Such a subnormal barrier as is here described is formed by the juxtaposition of two alluvial cones in the Engadine and at least one place in India.

Accidental Alluvial Terraces.

There might also be accidental variations during normal river development which in several instances would have an important influence on the relations between the load and the carrying power of a stream. The first of these may be dismissed with a few words, for the effect would be similar to that caused by a subnormal barrier in a stream, the difference being that in one case the barrier itself occurs as a subnormal feature of the river's life, while in the other case it is purely accidental. For instance, a timber dam, a beaver dam, or an artificial dam thrown across a stream might cause the building of an alluvial plain which would certainly be dissected and possibly terraced when that barrier was overcome. However, such a terrace would hardly be sufficiently long lived to cause the formation of well-marked topographical features. If the barrier were of glacial or volcanic origin, the effect might be felt for a longer time and the influence might be considerable, as we know for instance that many rivers in glaciated areas were seriously impeded in their course by the dams left during glacial times, and such dams have had an important modifying influence on the work of the streams of such areas. Lava obstructions occur in a few cases and specific instances of their effects are therefore rare.

Another glacial accident whereby an alluvial plain might be formed, is where a surcharged river suddenly emerges from beneath a glacier. The relief from the pressure of the overlying ice sheet would cause an immediate deposition of the greater part of the waste carried while under pressure; the removal of portions of this would form terraces. In this manner the terrace plain, if not the whole terrace, would be due to a glacial accident. An alluvial plain due to a much rarer glacial

accident might be formed where a glacial front advancing into the headwaters of a river system thereby furnished a much larger load than it would be possible for the stream to remove if its volume remained constant. The effect would be an immediate overloading of the stream and consequently the formation of an alluvial plain which might be terraced later, when the glacier had retreated. The terraces in the headwaters of certain rivers of northwestern Pennsylvania seem to have been formed in this manner.

Composite Alluvial Terraces.

As I have already mentioned, composite terraces are those due to some terrace-making process which, beginning in one cycle, closes in a subsequent one, being thus the result of a continuous process acting in a river valley while the continent as a whole was rising or sinking. Consider for instance the case of a river which had reduced the greater part of its drainage area to base-level in one cycle and was wandering across an alluvial plain. If the land mass was then raised, the river would be rejuvenated and would at once begin to cut a channel in the previously accumulated alluvial deposits. The terrace plain would thus have been formed in one cycle, the escarpment in the succeeding cycle; and the terrace as a whole would be composite in character. It seems probable, as I shall try to show in this paper later on, that many of the famous terraces in the northern portion of the United States are composite in character.

Complex or Involved Alluvial Terraces.

Involved terraces, or as it seems better to call them, complex terraces are those due to a combination of causes acting jointly or in succession, and continuing through the whole or part of one or more geographical cycles. If we could know all the factors that have determined the formation of most of the terraces we see at the present day, I think that we should find them to be better classed as complex terraces than under any other heading in the classification thus far proposed.

If we follow the deductive scheme outlined above, river terraces may be classified as follows.

Planation terraces . . . . not farther considered.

- Alluvial terraces.
  - simple
    - normal .
      - old age?
      - capture.
      - discovery of hard beds.
    - subnormal
      - climatic.
      - barrier from alluvial cone, talus, land slide, etc.
      - reversed gradient.
    - accidental
      - barrier by timber, beaver, lava, or artificial dam.
      - glacial
        - obstructive.
        - overloading.
  - composite . . .
    - rising of land.
    - continuation of any factor to a later cycle.
  - complex . . .
    - complicated in origin and not capable of classification.

Conditions of Terrace Formation.

Let us now pass from a deductive consideration of the probable cause of alluvial terraces to an examination of the actual conditions as they appear in many terraced river valleys. The top of the highest terrace represents the original line of the alluvial plain of the stream in which the terrace was formed, and the escarpment shows the depth to which the river cut before the next plain was formed, and hence it is difficult at first to see why there should be more than one terrace in a river valley, if we consider the erosive processes to be uniformly continuous. It is especially hard to account for the formation of ten or more terraces in regular order on the sides of a valley ; for instance, in certain portions of the Connecticut valley. The terraces above the present level of the river are the remnants of the oldest flood plain of the river, and the question at once arises why a river should so frequently leave such remnants in its down cutting. Why should it not, as soon as it has cut its channel as low as it can into the deposits under the existing conditions of base-level, swing back and forth across its

valley until it has undercut and removed all the deposits remaining upon the sides of the valley down to that base-level? If it should do this work in every case it is obvious that there would never be at any one time more than one terrace in a river valley, and after a sufficiently long time there would be none at all, for all the land would be cut down to the level of the stream itself. This idea is well stated by Prof. James Geikie[1] when he says, "Should the stream continue to flow with the same volume and under the same conditions, the newer flats would eventually come to occupy as broad a space as that formerly covered by the older terraces, the latter in fact would be completely demolished." In order to account for two or more terraces in a river valley it is necessary to determine why the width of the flood plain of the stream should become less and less as the valley is cut deeper and deeper into the deposits. In other words, why lateral cutting should decrease under these conditions.

Previous study of the physics of river erosion has shown that with a land nearly reduced to base-level, the tendency of a river is to cut laterally rather than to deepen its channel. Under the opposite conditions of a high or rising land, the tendency would be for the streams to cut down their channels deeper and deeper until they had come as close to base-level as they could. Keeping these facts in mind it becomes an easy matter to account for numerous terraces at any one place in so many of the streams of the northern United States and Canada, if we remember that, as far as we know, the land in these regions began to rise at the close of the glacial period and has been rising ever since. Consequently a stream of constant volume cutting down into the deposits previously dropped in the valley, would tend to leave many terraces, for each terrace plain would represent the temporary alluvial plain level of the stream. If the present geographical cycle continues until the stream has cut nearly to base-level, lateral wearing will undoubtedly be stronger than now, and the present terraces will be successively undercut and disappear. No conditions that we know at present, that do not allow the river to decrease the radius of its swings as it cuts downward, could form more than one terrace; although one terrace might

[1] Prehistoric Europe, p. 409.

be left temporarily while the river was cutting down to its base-level immediately after the inauguration of a new cycle. Terrace-making due to a stream of constant volume cutting down into a rising land is well illustrated by Hugh Miller[1], who gives an interesting account of such a process, based on his investigations of a small stream in England that was forming terraces rapidly.

The explanation given above seems to account for the formation of the greater number of existing terraces, namely, those formed in the river valleys influenced by the action of the last ice age. Of such terraced valleys that of the Connecticut is the best known though it shows us no finer terraces than those found in many of the valleys of Canada and of New Brunswick.

Such terraces, according to the classification given above, are best described as complex. The upper terrace plain was formed during glacial times and the rest of the work has been subsequent, and is due to a different cause from glaciation. The process of formation was probably something as follows. Streams that under the pressure of the confining ice sheet were capable of carrying great loads dropped them on issuing from under the ice sheet, and have built deposits in front of their mouths, of the flood plain type, such as are described by Mr. Russell[2] in the valleys of the Alaskan rivers. The rivers, overcharged with detritus and flowing out upon a land that had a slope too slight to allow all the detritus to be transported by the existing volume, would at once begin to aggrade their valleys to a slope adjusted to the load and to the carrying power. As the level of the valley deposits gradually rose to the required grade, the ability of the stream to carry material at that point would increase, and the waste deposited would naturally grow coarser because the size of the transported particles would vary directly with the carrying power. Consequently many of the alluvial terraces formed during the last ice time should present materials gradually increasing in coarseness from the bottom upwards. An examination of the materials in certain of the terraces in glaciated

[1] River terracing, its methods and their results. Proc. roy. phys. soc. Edinb., session 112, 1882–3, 1883, p. 263–305.

[2] Second expedition to Mt. St. Elias. Thirteenth Annual report U. S. geol. survey, p. 57.

valleys, as for instance those in the Connecticut valley just to the south of Brattleboro, Vermont, shows just such a variation in the size of the particles exposed in sections of terraces.

It is often found in the terraces of the Connecticut valley that the material suddenly changes from fine to coarse as one ascends the terrace escarpment. This seems to me to be well explained if we imagine that the terrace deposits were formed in many cases in temporary lake basins, caused by a glacial or accidental barrier down stream. If that barrier should suddenly be removed, as well might be the case, the rapidity of the stream would at once be increased and it would begin to drop coarser fragments than had hitherto been deposited at that place. The same fact has been stated by Mr. Robert Chalmers of the Canadian geological survey when he says, "the materials are water worn gravels and sand with a few small boulders, and usually become coarser toward the summit. The lower terraces are usually capped with loam of various depths. Boulder clay often underlies them especially in the upper slopes of valleys."[1]

The theory given above for accounting for glacial terraces is a modification of the plan proposed by Mr. Chalmers, which is as follows:—

"The generally accepted theory that river terraces have been formed at the close of the glacial period and subsequently denuded in part, as the volume of the water decreased and became confined to narrower channels, thus cutting down into their original deposits, seems to be only partially correct and to require modification and extension. Moreover this theory fails also to take into account the fact that these valleys, in certain places, were partially or wholly filled with masses of glacial drift during the ice age, sufficient to block them up nearly to the general level of the country on both sides. This is evidenced by the accumulations still occupying them in places, causing the diversion of the rivers from their preglacial channels. A more reasonable solution of the problem seems therefore to be, that on the final retreat of the ice sheet of the glacial period, the river valleys, or such portions of them as were then open between the embankments of glacial drift referred to, would be re-occupied by the precipitation of the river basin. These waters in portions of the river valleys form lakes or chains of lakes all tending to over-flow by the lowest passage which in most cases would be along the course of the preglacial valley. Erosion and the filling up of these lake-

[1] Report on the surface geology of southern New Brunswick. Geol. and nat. hist. surv. Can. Ann. rept., new ser., vol. 4, for 1888–89, p. 60, N.

like expansions with detritus would then commence, every tributary as well as the main river carrying down its contribution, which, wherever these river expansions were of considerable length, would be thrown down and form deltas and terraces. Gradually the smaller and narrower ones, more especially in their upper reaches, would become partially or wholly filled with detrital materials except in the passages of the channels of the river. As the embankment of the glacial drift referred to, holding in the lakes, became eroded and the river's passage through them deepened coincidentally with a lowering of the waters, these partially filled lake-like expansions would assume the river-like form, and eventually become a part thereof, and terraces appear along the sides. Finally, by erosion and the deepening of the river's channel, it would reach a comparatively even flood plain, and as it became more and more confined to a narrow channel, other and lower terraces would appear along its border from time to time. In this way might the terrace have been formed without supposing the existence of enormous floods and rapidly dissolving glaciers. Indeed the view here given does not require that the rivers be very much greater in volume than they now are."[1]

I propose a modification of the plan given above for the formation of alluvial terraces in glaciated valleys, that seems to me to accord better with the facts as we find them in such large rivers as the Connecticut, in which no system of lakes could well account for the formation of all the terraces, though it may account for some of them. The Connecticut River occupies such a well-marked valley that it must have been the drainage channel of a large amount of the water caused by the melting of the great glacier that overlay some portion of its valley. According to the plan that I have suggested, part, if not all, of the waste in the terraces must have been laid down during the immediate presence of the ice. Afterwards a decreased volume and a rising land will account for the rest of the work done in postglacial times. In other words, the upper terrace plain is due to a glacial accident in the river's history, and the upper escarpment was formed as the river cut down toward base-level after the land rose when relieved from the weight of the ice. The whole terrace is therefore complex in its origin. The later terraces formed as the river sank its channel deeper into the glacial waste, each terrace plain representing the temporary level of the stream and each escarpment showing intermittently rising land. Such an hypothesis is framed in accordance with the plan for the development of a

[1] Op. cit., p. 61 et seq.

river system as it has been given us by Professor Davis and accepted as a working basis by many geographers.

Conclusion.

As alluvial terraces occur in numbers only under peculiar and special conditions, it is very difficult to find examples of many of the terraces I have enumerated in my classification. The simplest normal terrace due to the old age of the stream would seem to be impossible or at any rate highly improbable. Consequently we are driven to the conclusion that a river will not exhibit terraces unless varying conditions act in such a manner as to bring about first the deposition of waste and later its partial removal. We need not be surprised at not finding terraces more frequently outside of the glaciated districts, for in no other case do we find for the reasons described above such favorable conditions for the development of alluvial terraces. The second best set of conditions seems to be found in the regions that undergo frequent changes of climate, alternating between increase and decrease of precipitation. Hence, we may say that river terraces are not normal but accidental developments of a river system.

It only remains to say in conclusion that it is often easy to confuse alluvial river terraces with other terraces, especially estuarine and lake terraces. Estuarine terraces may frequently merge into river terraces as the estuary becomes constricted into a true river. Lake terraces are especially confusing as they are often formed in re-entrants of a lake basin in such a manner that at first sight the basin seems to be part of a river system. They are, however, usually more continuous than river terraces. They appear not only in the re-entrants as benches of waste, but also upon exposed headlands as benches cut in the harder rocks by the force of the lake waves. As a lake is gradually drained away it may form terraces at every temporary water level and hence the terrace benches may be very numerous at any one locality on the margin of the lake basin. Sea benches are not apt to be confused with any other form of bench, and hence need not be considered in this connection.

Note.—The literature on river terraces and alluvial terraces is very extensive. In addition to the writings of Davis, Gilbert,

E. Hitchcock, Dana, Geikie, Upham, and others, I have found the following papers especially useful regarding the method of formation of alluvial terraces.

Hugh Miller, River terracing, its methods and their results. Proc. roy. phys. soc. Edinb., 1883.

C. B. Brown, On the ancient river deposits of the Amazon. Quart. journ. geol. soc. Lond., v. 35.

R. Chalmers, Geol. and nat. hist. surv. Can. Ann. rept., new ser., vol. 1, for 1885, GG. Ann. rept., new ser., vol. 4, for 1888–89, N.

McGee, The Pleistocene history of northeastern Iowa. Eleventh Annual report U. S. geol. survey, p. 189–577.

Professor Niles remarked that last summer in company with some students he had observed a sand plain which afforded evidence that the wind had aided in the accumulation of the material. The plain is located south of the village of Keesville, N. Y., and its western limit is bounded by the Ausable River. The levelings made by the party showed the surface to vary from five hundred to five hundred and twenty-five feet above sea level. About a foot below the surface there occurs a thin layer composed in part of charcoal. This layer was found in different parts of the plain, which is quite a large one for one of its kind. From the study made it was concluded that the sand lying above the charcoal had been brought there and deposited by the action of the wind. Professor Niles thought that there were but few sand plains in this region which had received so large a contribution by the agency of the wind.

General Meeting, April 4, 1894.

President W. H. Niles in the chair. Forty-nine persons present.

Prof. F. W. Putnam gave an account of the department of ethnology at the World's Columbian Exposition, calling attention to the many collections which were in the department, particularly those which were obtained by the several assistants whom he sent into the field in various parts of North, Central,

and South America. He dwelt with special emphasis upon the anthropological laboratory with its sections of anthropometry, psychology, neurology, and physical development. The communication was illustrated with a series of lantern slides representing the many exhibits, and as each picture was thrown upon the screen, Professor Putnam gave an account of the special features of the exhibit. He paid a tribute to the local directors of the Exposition for their ready acquiescence in all his plans and particularly for their willingness to furnish the means of carrying on original research, by which he was enabled not only to send seventy-five assistants to the various Indian tribes of America to make anthropological observations, but also to send expeditions to Central and South America, and to carry on explorations in the Ohio and Delaware valleys. Professor Putnam stated that never before, in three years' time, had so much been done in American archaeology and ethnology and physical anthropology, and that the results obtained had furnished a mass of new facts of great importance to science. He expressed his gratitude to the numerous assistants who aided him in this work, and was glad to say that one of the results of the department of ethnology in the Exposition was the founding of a museum in Chicago, to which the archaeological and ethnological collections were transferred, and where many other collections secured by gift or purchase from various exhibits in the Exposition are now being arranged by Dr. Franz Boas, who was chief assistant in the Department.

General Meeting, April 18, 1894.

President W. H. Niles in the chair. Thirty persons present.

It was announced that Mrs. Eliza F. Hammond, and Messrs. D. D. Slade, William H. Sylvester, and Samuel F. Tower had been elected Corporate Members of the Society.

Mr. N. T. Kidder for the committee to nominate officers for 1894–95 presented a report.

Mr. Herbert Lyon Jones spoke on the adaptations of fruits and seeds for the purpose of distribution.

Dr. B. L. Robinson remarked upon the reasons, means, and advantages of the climbing habit among plants, especially tropical climbers.

Annual Meeting, May 2, 1894.

President W. H. Niles in the chair. Forty-nine persons present.

The following reports were presented :—

Report of the Curator, Alpheus Hyatt.

The most remarkable accession of the year has been the gift of stuffed mammals, birds, and reptiles from the Boston museum. The history of the collection has been given, so far as related to the earlier years of its existence, in an article in the Boston herald printed soon after it was removed from the Boston museum building. It began its public life in 1818 in the hands of Mr. E. A. Greenwood, who exhibited on Court Street. It combined at this time and subsequently what was then called the New York museum, said to have been exhibited in Boston in 1812, Mix's museum purchased in New Haven, and what was called the Columbian museum, the latter, however, being described as a collection of wax figures. The museum was incorporated about 1818, under the title of the New England museum and gallery of the fine arts, as I am informed by Mr. Moses Kimball, but eventually fell entirely into the hands of Mr. Greenwood, and about 1835–36 passed by purchase into the hands of the Kimballs. Moses Kimball moved the collection to the building now occupied by the Methodist Church on Bromfield Street, and while it was piled up there it underwent revision. The portions selected out as unfit for exhibition in Boston were sent to Lowell and utilized in that city, and the remainder became the nucleus of the future museum in this city. In 1841 the collection was transferred to a building which stood on the site of what is now Horticultural Hall, and it was then called by Mr. Kimball the Boston museum. Financial prosperity began in this building, and in 1846, the building on Tremont Street, between School and Court Streets, having been put up, the museum was transferred to that site. There was a large amount of room in this new building, and Mr. Kimball, who was an enthusiastic collector as well as a business man, bought largely and employed collectors. One half of the

Peale collection was thus obtained from Philadelphia. This was then stored in Masonic Hall, Philadelphia, and was bought by P. T. Barnum and Mr. Kimball together and divided between them. The smaller elephant in a crouching position, now in our possession, came from this historical collection, and also most of the larger quadrupeds and birds. The giraffe, however, and the large elephant, and most of the game birds, were purchased by Mr. Kimball. The skeleton of this elephant and the skin are parts of the same animal. The leather-back turtles, also parts of the Peale collection, both came from the Delaware River, and were among the first ever captured and preserved. These and many interesting details of the history of this collection have come to the Curator through the kindness of Mr. Kimball, and it is hoped that in the course of further work upon the specimens it may be practicable to obtain the history of most of them.

The acquisition of this collection was attended with certain difficulties. It had to be removed within three days, and as it included a number of large specimens, this obliged the Executive Committee to take the responsibility of accepting the gift and the expenses of the removal and installation without formal action of the Council. These expenses, including a large amount of taxidermist's work subsequently done, came to about one thousand dollars. This was fortunately met in part by economy in other directions.

The difficulties attending the removal of the stuffed elephants were considerable. The superintendent of police refused to allow them to be taken out and carted through the streets until midnight, and they had to be brought here at that unseasonable hour. There was no door in this building which would allow them to enter, and they had to be hoisted and put through one of the front hall windows in the early hours of the morning. The stuffed skins were stored in the lecture room of the Society, and this hall where I am now reading became for the entire summer a Noah's Ark that saved them for the future uses of science. Photographs of this congress of the beasts were made at the time and were exhibited later. The old cases in which the specimens were stored in the Boston Museum were given with the collection, and these were reset in our hall and have been successfully used to meet the immediate demands for storage. These cases,

however, have solid ends and are dark in consequence of this and of old-fashioned small panes, which also interfere with the observation of the specimens. The sashes also are so large that every time a case is opened, it requires a couple of men to unscrew a sash and handle it. After the labeling has been completed and the cases screwed up tightly, the collection will be practically inaccessible.

The department of Mammalia was almost unrepresented in our Museum, so that the accession of this collection was very desirable, but the old-fashioned cases in which it is stored and the crowding of the main hall occasioned by them are serious defects. The latter especially needs to be remedied, and it is to be hoped that the expense of building new cases and relieving our main hall so that the guide can do his work with more facility may be met by special donations and not fall upon the unaided income of the Society.

As in past years, our Museum has been used more or less by classes from the Massachusetts Institute of Technology and from Boston University, and by a greater or less number of students studying separately in the collections on closed days. Permission to visit and study in the Museum on days when the public is not admitted has been granted to eleven teachers, representing nine schools and 127 pupils. This of course does not include the teachers and classes that come on public days.

It will be noticed that this year no report is made by the Board of Directors of the Natural History Gardens and Aquaria. This Board resigned at the meeting of the Council of October 16, 1893, and recommended the return of the subscriptions already paid to them. The Board of Directors, when the Curator was a member of it and had personal knowledge of its doings, and subsequently, have made the most strenuous efforts to interest the influential and wealthy citizens of Boston and to obtain subscriptions from them. The composition of the last Board was such as to insure success, if success had been possible, and their work has made it evident that the necessary funds could not be obtained in this city; in other words, that up to the present date, sufficient interest does not appear to exist among our wealthy men to induce them to give the money to found natural history gardens and aquaria. It is idle to give the long history of all the efforts

that have been made; the statement just given is the result of the experience of the last Board, as well as the first, and of the personal efforts of several gentlemen, including the Curator, who have spent a large proportion of their time in soliciting subscriptions.

The financial conditions also have of late been averse to this undertaking, and it is therefore not to be wondered at that the Board of Directors have resigned and have recommended that the Society lay aside this design for the present.

The Council, in taking formal action upon the resignation of the Board, and in adopting their recommendation to return the few subscriptions that had been actually paid in, also concluded that it was their duty to communicate with the Park Commissioners, and it accordingly voted that the President, Prof. W. H. Niles, inform those gentlemen of the action it had taken. The Council has not yet had occasion for a further consideration of the matter. The letter of the President was as follows:—

BOSTON SOCIETY OF NATURAL HISTORY,
BOSTON, MASS., DECEMBER, 1893.

TO THE HONORABLE THE PARK COMMISSIONERS
OF THE CITY OF BOSTON,

GENTLEMEN:—At the last meeting of the Council of the Boston Society of Natural History, it was voted that the President inform you by letter of an action taken at that meeting. A vote had just been passed to abandon, for the present, an effort to secure funds for the establishment and support of Natural History Gardens and Aquaria. This vote was taken after a deliberate consideration at two sessions of the Council. The circumstances which led directly to this action were the following: The Directors appointed by the Council had met with little success in their efforts to secure contributions for the purpose, the public had not responded to their solicitations, the period within which they had been requested to secure the necessary funds had expired, and they had formally resigned their offices. It was felt that the unfortunate condition of the industrial and financial interests of the country made it injudicious, for the present, for the Society to attempt to raise such an amount of money by subscription. The Council believed that it would be unwise to make a beginning with less funds or with plans for smaller establishments than had been previously advocated. The plans of the Park Commissioners show reservations of ample and well-located areas for such gardens and aquaria, and they are regarded as expressing the

good intention that whatever may be done shall be *well* done and liberally supported.

It would have been a gratification to the officers and members of this Society to have assisted successfully in the establishment of Natural History Gardens and Aquaria, if in maintenance and completeness they might have harmonized with the system of parks now in existence and in process of construction. It was for the furtherance of this object that this Society was reorganized with suitable provisions in its By-Laws. This organization remains, for the present, unchanged, and it is consequently fitting for me to say, that, in this connection, the Council of the Society entertains no other scheme than the one well known to you.

The members of the Council of the Society have the pleasure of believing that with them and the Park Commissioners there has been a perfect harmony of opinion and desire regarding the character and conduct of gardens for the exhibition of living creatures.

In accordance with the request of the members of the Council of the Boston Society of Natural History, I hereby express their regret at not being able to complete their part of the provisional arrangement so agreeably made, and convey their thanks for the cordiality and liberality with which the Park Commissioners have received and encouraged their overtures.

I have the honor to remain,

Yours respectfully,

(Signed) WM. H. NILES,

President, Boston Society of Natural History.

The Curator wishes to draw attention specifically to two items in this report. The first is, the scientific investigations of Professor Crosby in his department and the need of keeping up and providing for such work if we desire to do our part in the history of science in New England; we are essentially a local society and ought to do a large part of the local work.

The second is, the advance made in the Teachers' School of Science through its connection with the Normal School. This is at present temporary and may of course never become permanent, but it is nevertheless, so far as the objects of the Teachers' School of Science are concerned, the consummation of the hopes of the last twenty years. The Curator considered this union desirable and has made efforts towards this end, as far as circumstances permitted, ever since 1870, but without avail. It has come now through the action of the teachers themselves, and is consequently more apt to be permanent than if it had been forced by outside pressure.

Teaching in the Museum.

This work is still maintained by the liberality of a Boston lady who appreciates our work in this direction and hopes that it may be made a permanent department.

The attendance, meaning by this those who listened to the guide and followed him more or less through the Museum, has sensibly increased this year, and the guide reports greater interest on the part of the public. He reports that persons who have heard the general lectures are apt to return with a desire to get further instruction upon some special subjects that have interested them, and also that his attention has been called to some persons who have come several times so as to hear the lesson repeated by the guide. A small number of persons have through the interest thus excited been led to purchase copies of the guide books on mineralogy and geology in order to examine and study more specifically in those collections.

The estimates of the numbers reported as having listened to the guide are necessarily defective, because of the difficulty of obtaining any accurate count, but they are as follows: 1893, May, 436; Sept., 497; Oct., 470; Nov., 193; 1894, April, 387.

This department has been enlarged during the present year by the granting of special privileges to a class of thirteen advanced students under the direction of their teacher, Miss Dora Williams. This class has systematically visited and studied in the Museum twice a week during February and March, and have also made other visits for the purpose of studying more specially the collection of minerals and rocks, using Professor Crosby's guide-books as aids in this work.

Dynamical Zoology.

The work upon this collection has been steadily progressing. The mounting of the species of Achatinellinae upon the duplicate relief map of Oahu is well advanced, so far as the experimental part of the undertaking is concerned. This is unexpected good fortune, since in his last report the Curator had no hopes of getting to this point for a year or more. The plate showing the evolution of the Arietidae has been completed and hung in its place. A set of mounted plants illustrating the action of similar

habitats upon the shapes of plants has also been obtained and mounted by Miss Martin, but they have not yet been labeled because of the difficulty of preparing comparative labels until the whole series of plants is completed. A few additional models have also been made and mounted by Miss Martin.

Geology.

This department has at last attained a stage of advancement which will enable the assistant in charge to devote most of his time to investigation. As a matter of fact, this has been the case in certain proportion for several years, but during this time a considerable amount of manual labor remained to be done upon the collections. Although they will need to be revised and more or less extensively changed every few years in order to keep even with the progress of science, the necessity for a large amount of manual labor will probably not recur while they remain in their present rooms. The mineralogy needs revision now, as was stated in the last annual report, and this cannot be much longer delayed. It is to be hoped that all the departments of the New England series may be equally well developed and furnish similar opportunities for investigators who are willing to devote themselves to original work.

Professor Crosby's time during the past year has been devoted almost wholly to the prosecution of the systematic study of the Boston Basin, and the collection and arrangement of material to illustrate the local geology. The first part of this work (Nantasket and Cohasset) was ready for distribution early in the autumn. The second part (Hingham) has been made ready for the printer.

The third part, which embraces the Blue Hill area, is nearly completed. This part is of exceptional interest because it includes the principal Cambrian outcrops of eastern Massachusetts, and because the Blue Hill range is the dividing wall between the Norfolk and Boston Basins.

"Mr. T. A. Watson has found the characteristic middle Cambrian fossil, *Paradoxides harlani*, at a point about a mile southeast of the original and celebrated locality on Hayward's Creek; and has kindly presented the specimen, which shows part of the thorax of an unusually large individual, to the Society. The lithological character of the strata indicates that the slates of the Blue Hill

area are chiefly middle Cambrian. But we have also proved that the lower Cambrian or Olenellus zone has an important development here, both east and west of Weymouth Fore River, the beds bearing a striking resemblance to those of North Attleboro. With the assistance of Mr. Watson, and by taking advantage of the opportunities afforded by recent excavations, the known area of the Cambrian slates in this region has been considerably extended; and the Monatiquot River belt has thus been traced westward to where it, apparently, passes beneath the Carboniferous strata of the Norfolk Basin."

"The intricate relations of the Cambrian slates to the Blue Hill granites have been carefully traced out over the entire area, and illustrated by special maps and sections. The granite is everywhere clearly newer than the slate and eruptive through it. Two kinds of contacts have been demonstrated—original or igneous contacts and fault contacts; and the distinction of these is essential to the correct interpretation of the geologic structure."

"The stratigraphic and topographic relations of the felsite forming the main range of the Blue Hills have received particular attention, and satisfactory conclusions have been reached. Its topographic prominence is accounted for by the facts that it belongs normally above the granite and slate, and that it is a harder and more resistant rock. The Blue Hill complex is shown to be a composite fault-block, the principal transverse displacement marking the eastern end both of the felsite area and the Norfolk Basin. It is the tilting of this orographic block that has separated the Norfolk and Boston Basins, the displacements amounting to thousands of feet. These studies indicate that the Carboniferous strata of the Norfolk Basin once extended over the Blue Hill complex, and also that the faulting and tilting date from the Appalachian revolution. It follows from this, that the conglomerate series and newer slates of the Boston Basin, the age of which has been so long a matter of controversy, are probably also Carboniferous."

"Incidentally to the study of the glacial geology of this region, an investigation of the paleontology of the drift hills or drumlins has been made. As a result, the number of localities where fossil shells are known to occur has been considerably increased; and the number of known species has been at least doubled. The list of forms in the drift fauna of the Boston Basin now embraces

over forty well-determined species. A carefully selected and nearly complete series of these fossils has been added to the illustrations of the local geology in Room B. During the collection and study of these drift fossils facts have come to light which indicate that they may be of late Tertiary instead of Quaternary age; and, although no certainly extinct species is yet known, it appears not improbable that Tertiary strata now underlie the deeper parts of Boston Harbor."

The arrangement of the specimens to illustrate the geology of the Boston Basin has been commenced in sections 24 to 26 of the wall-case in Room B. The collections for Nantasket, Cohasset, and Hingham are now in order, and it is proposed to extend the series with the completion of each part of the work. It is hoped to make this exhibit so effective that it will prove of real value to teachers and students, serving not only to illustrate the text, but for the identification of material collected or observed in the field.

Through the generosity of Mr. Watson, three reading tables have been added to the Geological Department. These have been placed in the Vestibule, Room A, and Room B, and provided with copies of the Mineralogical and Geological Guides, and Part I. of the Geology of the Boston Basin. This innovation is evidently appreciated by the public, for although the books are in quite constant use on exhibition days, they have received as yet no serious injury.

Botany.

Mr. John Cummings still continues to take care of this collection, and the indebtedness of the Society to him has been increased by another year of service. Owing to unavoidable delays and to unusual demand upon the time of the assistant by outside work, the final and complete report upon the herbarium cannot be given as was expected. Miss Carter has, however, been able to accomplish considerable in the various parts of the collection. A large amount of time has been devoted to the Fungi, the collection of which has been enriched by the addition of two foreign collections, and now contains 321 genera, 2,239 species, and 4,024 specimens; the fascicles of Seymour and Earles's Economic Fungi, as far as published, have also been obtained. The following accessions are hereby acknowledged: Miss Cora H. Clarke, 67 speci-

mens New England Algae; Mr. G. H. Mackay, 1 specimen for New England collection.

Twenty-six persons have been allowed the use of the herbarium, and very much more time devoted to this work than in any previous year; probably an entire month of the assistant's time has been devoted to this purpose.

Synoptic Collection.

The Society is indebted to Miss J. M. Arms for the large amount of unpaid work which has been done by her upon this collection. This is of essential importance to the progress of the Museum, the synoptic collection being the key to all other organic collections.

The text of the guide to Porifera has been enlarged by Miss Arms, and 12 plates with 78 figures, illustrating the structure and development of sponges, have been completed by Miss Martin, and are ready for the cases. Specimens of Corynoides (accompanied by an enlarged drawing of the same), Monograptus, and Diplograptus have been added to the Hydrozoa.

From 80 to 100 manuscript pages of text have been prepared on the Actinozoa and Echinodermata. The Actinozoa have received a fine alcoholic specimen of *Metridium marginatum* from Mr. Alfred Goldsborough Mayer.

Two plates illustrating the growth of coral, a drawing of the parasite, Bicidium, and a plate of thirty-six drawings giving the development of Renilla have also been completed by Miss Martin.

Specimens of crinoids have been selected to illustrate the classification adopted. An alcoholic specimen of Pecten has been added to the lamellibranchs, and specimens of the sea-hermit, *Petuchirus granulatus* Stm., and its parasite, *Porcellana ocellata* (from Miss J. M. Arms) to the Crustacea.

The remainder of the Assistant's time has been spent on mollusks, chiefly on cephalopods.

Paleontology.

The Society is under obligations to Miss Hetty O. Ballard for having acted as voluntary assistant during the past year. Revised labels for specimens to be retained on exhibition have

been prepared, ranging through the lower formations from the Cambrian to the Hudson River inclusive, and embracing in the Cambrian Scolithus, brachiopods, pteropods, and trilobites; and in the Lower Silurian corals, crinoids, brachiopods, lamellibranchs, gasteropods, and pteropods, also the few cephalopods of the Black River group; in all 58 genera and 87 species. One hundred and thirty tablets containing one or more specimens have been excluded and marked as duplicates. Thirty-four tablets of St. Johns group fossils, from Professor Matthews, have been studied, and 16 of these marked to be retained. A collection made by Professor Bailey from the same group has been carefully examined preparatory to cataloguing, but it has been thought best not to finish the work on these two collections until other specimens of the same age have been received.

Porifera.

All of the sponges not on exhibition have been gone over by the Curator, aided by Mrs. Flint, and rearranged and stored in the topmost work-room on the north side of this building leading off gallery Q. The Curator's collection of alcoholic sponges, containing the counterparts of numerous unpublished colored drawings, has all been worked over. The specimens have been compared with the drawings by Mrs. Flint, and the whole series secured by a duplicate system of labeling. If we are ever able to find any one who will take up the investigation of the faunas of New England, as Professor Crosby has the geology, these collections will prove to be of great value and ought to save much time and labor.

Mollusca.

The Curator has worked, a large part of his time, upon this collection, and has been aided more or less by Mrs. Flint in some part of the work. Miss Martin has dusted and remounted the specimens on the tablets of a considerable portion of the collection on exhibition.

Insecta.

Mr. Henshaw, in addition to the general oversight of the collection, has identified and arranged portions of the Hymenoptera, Coleoptera, and Hemiptera.

Ornithology.

The Society is indebted to Mr. C. B. Cory for his care of this department. Considerable manual labor has been done during the past year, Mrs. Flint having spent the major part of her time for several months in dusting and cleaning the birds and stands and the shelving of the cases under superintendence of the Curator.

New England Collection.

Considerable work has been done in examining and cleaning the stored parts of the alcoholic zoology of New England by the Curator assisted by Mrs. Flint. The Curator's collection of alcoholic Bryozoa and other collections have been more or less reviewed, and the safety of the specimens looked after.

Laboratory.

The room of this department has been used as in previous years by classes from the Boston University and by two classes of the Teachers' School of Science on Saturdays. It must also be noted that the use of this room has been granted for the past year to an advanced class of the Normal School, which has come once a week, and consists of twenty-four students.

Mr. A. W. Grabau has rearranged in natural order the collection of fossils, placing them in paper and wooden trays made in such proportion as completely to fill the drawers of the cabinet.

Teachers' School of Science.

There has been a noteworthy advance made in this department during the year past, which was referred to in the first part of this report. An effort has been made to enlarge the curriculum of the Normal School in the direction of natural history work. It is not necessary to go into any details, but the results can be stated. The master of the Normal School has been allowed to enlarge the opportunities for study, and to offer voluntary courses in natural history to certain classes. No provision, however, has

been made to support these reforms with extra teachers or with supplies of various kinds needed for effective objective teaching. It was therefore possible that this movement, which the Teachers' School of Science has been actively helping to accomplish so many years, might fail at the outset from the want of proper facilities that could be offered to the students. With these considerations in view, the Executive Committee granted the use of the Laboratory and its diagrams and microscopes to the Normal School gratuitously, and special privileges in the Museum were also given, as related above. Miss J. M. Arms also kindly volunteered to give a normal course in elementary zoology, using our Laboratory for her class. This course is not yet finished. The President, assisted by Mr. Barton of the Institute of Technology, has also volunteered to give a series of lessons on geology, and these have been begun. The results of these courses will be given in the next annual report.

The class to whom these advantages have been given will graduate September next, and consists of sixteen young women who have expressed a desire to fit themselves to teach natural history in the public schools. Dr. Dunton, principal of the Normal School, and the teachers of natural history in his school have requested the Curator to thank the Society and its officers for the timely aid afforded them during the past year.

The Lowell Free Courses in the Teachers' School of Science have been as follows:—

The field course in geology by Mr. G. H. Barton, referred to in the last annual report as the spring course and begun on April 22, before the expiration of the last official year, consisted of nine lessons and excursions ending June 24. One excursion to Mt. Holyoke occupied two entire days. The average attendance was 63.40. The similar course given in the autumn consisted of ten lessons and excursions beginning on September 9 and ending on the 11th of November; the average attendance was 67.33. One excursion was to the Hoosac Tunnel, and this also took two days.

With the opening of the field lessons last autumn a more definite and systematic course of instruction in field work was devised. The system pursued was to begin with places adapted to the study of the simpler problems and gradually pass on to those which furnished more complex ones. At first the instructor did the larger share of the work, pointing out the phenomena and

explaining their meaning, but later in the course the class was required to make their own observations, under direction of the instructor, and to be ready to give explanations of their observations. The class are requested to take notes in the field, and on the succeeding week to hand in a detailed account of the work done and phenomena seen, with as full explanation as possible. Although this system involves a large amount of work for the instructor, it has been found to produce good results. As far as possible the work of the class is confined to the neighborhood of Boston, but to cover the ground satisfactorily several distant places have been visited. The large attendance at these lessons, while showing the growth of the demand for such instruction, acts disadvantageously to a certain extent, since it is not possible for an instructor to handle so large a number so well as a smaller class.

The winter's lessons in mineralogy, also given by Mr. Barton, were the last series in a four years' course. Tickets were issued only to those who had been members of the class during previous years, these alone being fitted to continue in this course. The total number of tickets given out was forty-eight. During the course, sickness became prevalent, and several were obliged to leave the class, and a few new members were allowed to join in their places, but tickets were not issued to them. Owing to the large number in the class, subdivision became necessary, and two sections were formed of twenty-four members each. The first section began on November 28, 1893, and continued to February 24, 1894, receiving fifteen lessons. By unanimous vote of this section a sixteenth lesson was requested and given. The average attendance was 19.56. The second section began on January 13, 1894, and continued to April 21, 1894. This section also petitioned for an extra lesson, but owing to the immediate beginning of the field lessons, this could not be granted. The average attendance was 20.73.

The method of instruction has been nearly the same as that of preceding years. Each exercise has been two hours in length, so divided as to give one hour to work with the specimens under direct guidance of the instructor, one half hour to a general review by lecture, and one half hour to an examination covering all the ground from the beginning of the course to the time of giving the examination. With the first section twelve of these

examinations were given, and with the second section ten were given. No final examination was considered necessary in either section. The class has been very enthusiastic, and as a whole has done good work, though an unusual amount of sickness interfered seriously with the attendance of several members.

The spring course in geology for 1894 was begun by Mr. Barton on April 28, with an attendance of 75 members, and is now in progress.

The class in botany began its exercises November 4, 1893, and ended on March 10, 1894. Fifteen lectures and laboratory exercises were given followed by a formal examination at the close of the course. Forty-nine applicants were admitted to the class, thirty-two of whom were former members. Of these, eleven members dropped out in the first one or two exercises, on learning that the course was to be a continuation of preceding courses, so that the class practically consisted of thirty-eight members. The average attendance was thirty-four.

The subject studied during the year was cryptogamic botany. The leading types were exemplified, together with their relations to each other and to the phaenogams studied in preceding years. A somewhat similar plan of presentation to that pursued last year was adopted, but owing to the difficulties incident to the wider range of subjects and the limited facilities for illustration, it was found to be less satisfactory, though well adapted for the purposes of the course. For illustration one hundred sets of cryptogamic plants, chiefly ferns, mosses, lichens, and certain fungi, were collected and dried, so that each member of the class was amply provided with material for study. To this was added abundant fresh material, as in the groups of sea-weeds, moulds, and the lowest cryptogams, as yeast. Compound microscopes were provided in the exercises requiring their use; and microscopic preparations, blackboard diagrams, and monographs on special subjects, from the library of the Society, were freely used for further illustration of the subject. The results of the work of the year, as shown in the short examinations which preceded each exercise, the note books, and especially the final examinations, were most gratifying. Twenty-nine persons took the final examination; of these fourteen passed with especial honor, receiving H = 90–100 per cent; six received C, 80–90 per cent; and nine others P = varying marks between 50 and 80 per cent.

None failed to pass, and several of the books were very nearly perfect.

Thirty-five members of the class have signified their desire to take the course in paleo-botany offered for next year to complete the course as originally planned.

Dr. Greenleaf desires to acknowledge this year as also last year his indebtedness to his assistants, Miss Jennie M. Jackson, Miss Helen Sharp, and Mr. Samuel F. Tower.

The series of special courses in historical geology and paleontology was continued by the Curator. Nineteen lessons were given, excluding the examination, beginning on November 4, 1893, and ending April 7; the examination was held April 28. The whole number of tickets issued was thirty, and the average attendance was twenty. This being the fourth year of this series accounts for the falling off in the number of the class. Fifteen persons took the examination, and the results show how completely the class had been weeded. The note books made during the term, the test with twelve specimens, and the answers to questions, upon which most of them wrote for four hours at the examination, all proved highly satisfactory, the average being far above that of last year. The Curator desires to thank Miss J. M. Arms and Miss Hetty O. Ballard for assistance in giving these lessons.

The Teachers' School of Science also took part in the exhibition of elementary science teaching made by certain teachers of the public schools of the eastern part of this State in the spring of 1893. The exhibit comprised a suite of large cards giving a list of lectures delivered since 1871 chronologically arranged, analyses of special courses then being carried on, and a synopsis of one lecture in each course accompanied by a series of the specimens used. There was also a collection showing samples of the specimens that had been used and given away in past years, and also a series of the books and models of various kinds that had been made to illustrate these lessons.

This exhibition was of solid benefit since it showed thousands of teachers what had been done and was still being done by this Society and by the Trustee of the Lowell Fund in aid of education, and it was worth all the labor and trouble that it cost.

The Society owes the opportunity to take part in this public exhibit to the generosity of Mr. T. A. Watson, who paid the expenses of preparation, installation, and attendance.

Report of the Secretary and Librarian, Samuel Henshaw.

Membership.

Nineteen Corporate members have been elected by the Council during the past year; five have died, one has resigned and one has been dropped for non-payment of dues. One Honorary member, Leonard Blomefield, and two Corresponding members, Edward Norton and Carl Semper, have died. Franklin Haven, a Patron, has died. By the death of Leonard Blomefield we have lost one of the earliest of our Honorary members; there are but two Corporate members on our list to-day that were members of the Society when Mr. Blomefield was elected, August 21, 1839.

The roll of the Society includes the names of 16 Honorary, 143 Corresponding, and 348 Corporate members, a total of 506.

Though we have this year made a gain of ten in the list of our Corporate members, it is especially desirable that attention should be called to the advantage of adding to our number, which has remained practically stationary for several years.

Meetings.

Fourteen meetings have been held. They have been especially well sustained, the total attendance 987, giving an average of 70 *plus* to a meeting, is more than has been recorded in any previous year. The largest attendance at any one meeting was 247, the smallest 27; the largest last year was 95 and the smallest 31; four meetings this year have had an attendance of more than one hundred, an event unrecorded in the annals of recent years.

Twenty-nine communications have been made by twenty-seven persons.

Library.

The additions to the library are as follows:—

	8vo.	4to.	Folio.	Total.
Volumes.	325	52	4	381
Parts.	1,851	424	3	2,278
Pamphlets.	350	42		392
Maps, photographs, etc.				18
			Total,	3,069

The total 3,069 exceeds the number recorded in any previous year.

The library contains 21,250 volumes, 1,229 incomplete (including current) volumes, and 9,992 pamphlets.

New exchanges have been arranged with six institutions as follows: Geographical club of Philadelphia; Guernsey society of natural science; Museo nacional Montevideo; Bohemian academy for natural science and literature (Prag); Geological survey of New South Wales; School of mining, Kingston, Ontario.

By purchase we have added nine serials, La cellule, Monitore zoologico italiano, Annals of botany, Journal de l'anatomie et de la physiologie, Nautilus, Memoirs of the national academy, Murray's Phycological memoirs, Recueil zoologique suisse, Bulletin of the department geology University of California.

The Society now exchanges its publications with 378 scientific societies and periodicals. A list of these exchanges, together with the serials received, is appended in the expectation that its publication will suggest desirable additions.

One thousand and sixty-eight books have been borrowed from the library by 111 persons, 305 books have been borrowed for use in the building, and the library has been consulted 542 times. These figures all show an increase over those of recent years.

Five hundred and seventy-six volumes have been bound in 409 covers. The indexing of serials commenced last year has been continued.

The list of the 12 serials, 183 volumes, indexed this year is as follows:—

Academy of natural sciences of Philadelphia, Journal (1st ser.).	8 vols.
American philosophical society, Transactions.	22 vols.
Annals of botany.	7 vols.
Jena. Medizinisch-naturwissenschaftliche gesellschaft, Denkschriften.	3 vols.
Johns Hopkins university, Studies from the biological laboratory.	5 vols.
Linnean society of London, Journal.	51 vols.
Museum of comparative zoology, Bulletin.	24 vols.
National academy, Memoirs.	6 vols.
Royal microscopical society, Journal.	16 vols.
Tryon's Manual of conchology.	21 vols.
U. S. department of agriculture, N. A. fauna (6 nos.).	3 vols.
Fish commission, Reports.	17 vols.

The total number indexed is 30 serials, 333 volumes; the current volumes of the serials reported on last year are indexed as received.

The new cases in the back library have somewhat relieved the overcrowded condition of a part of our shelves and enabled us to make a beginning towards a system of shelf classification which allows indefinite extension and does away with an expensive and discouraging rearrangement every few years.

Publications.

One number of the fourth volume of the Memoirs, containing Dr. Charles S. Minot's Bibliography of vertebrate embryology (128 pages), was issued last November.

We have also distributed part 1 of the 26th volume of the Proceedings, and 104 pages towards the second part are printed; this includes the copy of all papers in the hands of the Publishing Committee to date.

The distribution of the first part of the new volume of Occasional papers printed last year was unexpectedly delayed until November on account of difficulties in the preparation of the two special maps.

The repairs in the room used for the publications of the Society offered an opportunity for their rearrangement and more compact storage which is nearly completed.

Walker Prize.

The subjects announced for the annual award of the Walker Prize were as follows:—

1. The relations of inflorescence to cross-fertilization illustrated by the plants of eastern Massachusetts.
2. What depths of formerly overlying rocks, now removed by denudation, may be inferred from the structure of various rocks in eastern Massachusetts?
3. Experiments affording evidence for or against the theory of evolution.

Notwithstanding the greater range in subject thus afforded, only one essay has been received, and in accordance with the rules

of the Council the Committee, through their chairman Dr. Goodale, have informed the Secretary that they award a second prize of fifty dollars ($50.00) to the author of the essay entitled "A study of the Blue Hill complex with reference to the light which it throws upon the erosion problems of eastern Massachusetts," and bearing the motto :—

"The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands,
Like clouds they shape themselves and go."

The Committee also write :—

Your committee venture to suggest the desirability of announcing the subjects for essays two years instead of one year in advance.

APPENDIX.

LIST OF JOURNALS AND OF THE PUBLICATIONS OF SOCIETIES, SURVEYS, ETC., RECEIVED BY THE BOSTON SOCIETY OF NATURAL HISTORY.

Abbeville. Société d'émulation : Bulletin des procès-verbaux. Mémoires.
Academy of natural sciences of Philadelphia : Journal. Proceedings.
Academy of science of St. Louis : Transactions.
Agricultural and horticultural society of India : Journal.
Aix. Académie des sciences, agriculture, arts et belles-lettres : Mémoires. Séance publique.
Allgemeine schweizerische gesellschaft für die gesammten naturwissenschaften : Neue denkschriften.
Altenburg. Naturforschende gesellschaft des Osterlandes : Mitteilungen aus dem Osterlandes.
American academy of arts and sciences : Memoirs. Proceedings.
American agriculturist.
American antiquarian.
American association for the advancement of science : Proceedings.
American entomological society : Transactions.
American geologist.
American institute of mining engineers : Transactions.
American journal of psychology.
American journal of science.

American monthly microscopical journal.
American museum of natural history, New York: Annual report. Bulletin. Memoirs.
American naturalist.
American philosophical society: Proceedings. Transactions.
American society of naturalists: Records.
Amiens. Société linnéenne du nord de la France: Bulletin mensuel. Mémoires.
Amsterdam. Akademie van wetenschappen: Jaarboek. Verhandelingen; afd. letterkunde, afd. natuurkunde. Verslagen der zittingen van de wis- en natuurkundige afd. Verslagen en mededeelingen; afd. letterkunde, afd. natuurkunde.
Angers. Académie des sciences et belles-lettres: Mémoires.
Société d'agriculture, sciences et arts: Mémoires.
Société d'études scientifiques: Bulletin.
Annaes de sciencias naturaes.
Annales des mines.
Annales des sciences naturelles: zoologie.
Annals and magazine of natural history.
Annals of botany.
Anthropological institute of Great Britain and Ireland: Journal.
Anthropological society of Washington: American anthropologist. Special papers.
Anthropologie.
Archiv für anatomie und physiologie; anatomische abtheilung, physiologische abtheilung.
Archiv für anthropologie.
Archiv für mikroskopische anatomie.
Archiv für naturgeschichte.
Archives de biologie.
Archives de zoologie expérimentale et générale.
Arkansas. Geological survey: Annual report.
Asiatic society of Bengal: Journal (natural history part). Proceedings.
Asiatic society of Japan: Transactions.
Auch. Société française de botanique: Revue de botanique.
Augsburg. Naturwissenschaftlicher verein für Schwaben und Neuburg: Bericht.
Auk.
Australian museum, Sydney: Annual report. Records.
Auxerre. Société des sciences historiques et naturelles de l'Yonne: Bulletin.
Bamberg. Naturforschende gesellschaft: Bericht.
Basel. Naturforschende gesellschaft: Verhandlungen.
Batavia. Natuurkundige vereeniging in Nederlandsch Indië: Natuurkundig tijdschrift voor Nederlandsch Indië.
Beiträge zur biologie der pflanzen.

Belfast natural history and philosophical society: Proceedings.
Belfast naturalists' field club: Annual report.
Bergen. Bergens museum: Aarbog.
Berlin. Berliner gesellschaft für anthropologie, ethnologie, und urgeschichte: Verhandlungen.
Botanischer verein für die provinz Brandenburg: Verhandlungen.
Deutsche entomologische gesellschaft. Deutsche entomologische zeitschrift.
Deutsche geologische gesellschaft: Zeitschrift.
Entomologischer verein: Berliner entomologische zeitschrift.
Gesellschaft für erdkunde: Verhandlungen. Zeitschrift.
Gesellschaft naturforschender freunde: Sitzungsberichte.
Preussische akademie der wissenschaften: Abhandlungen; mathematische, physikalische. Sitzungsberichte.
Preussische geologische landesanstalt und bergakademie.
Bern. Naturforschende gesellschaft: Mittheilungen.
Berwickshire naturalists' club. History (proceedings).
Besançon. Société d'émulation du Doubs: Mémoires.
Société d'horticulture du Doubs: Bulletin.
Beziers. Société d'études des sciences naturelles: Bulletin.
Biological society of Washington: Proceedings.
Biologisches centralblatt.
Bologna. Accademia delle scienze dell' istituto: Memorie.
Bombay branch of the Royal Asiatic society: Journal.
Bonn. Naturhistorischer verein der preussischen Rheinlande, Westfalens und des Reg.-Bezirks Osnabrück: Correspondenzblatt. Verhandlungen.
Niederrheinische gesellschaft für natur- und heilkunde: Sitzungsberichte.
Bordeaux. Académie des sciences, belles-lettres et arts: Actes.
Commission météorologiques de la Gironde. Observations pluviométriques et thermométriques.
Société des sciences physiques et naturelles: Mémoires.
Société linnéenne: Actes.
Botanical gazette.
Botanical society of Edinburgh: Transactions and proceedings.
Braunschweig. Verein für naturwissenschaft: Jahresbericht.
Bregenz. Vorarlberger museum-verein: Jahresbericht.
Bremen. Naturwissenschaftlicher verein: Abhandlungen. Jahresbericht.
Breslau. Schlesische gesellschaft für vaterländische cultur: Jahresbericht.
Verein für schlesische insektenkunde: Zeitschrift für entomologie.
Brighton and Sussex natural history society: Annual report.
Bristol naturalists' society: List of officers, annual report, etc. Proceedings.
British museum: Catalogues, etc.

Brünn. Mährisch-schlesische gesellschaft zur beförderung des ackerbaues, der natur- und landeskunde: Mittheilungen. Notizenblatt der historisch-statistischen section.

Naturforschender verein: Bericht der meteorologischen commission. Verhandlungen.

Bruxelles. Académie des sciences, des lettres et des beaux-arts de Belgique: Annuaire. Bulletins des séances de la classe des sciences. Mémoires. Mémoires couronnés et autres mémoires. Mémoires couronnés et mémoires des savants étrangers.

Musée d'histoire naturelle de Belgique: Annales. Bulletin.

Société belge de microscopie: Annales. Bulletin.

Société de botanique de Belgique: Bulletin.

Société entomologique de Belgique: Annales.

Société malacologique de Belgique: Annales. Procès-verbaux des séances.

Budapest. Magyar nemzeti muzeum: Természetrajzi füzetek.

Ungarische geologische anstalt: Jahresbericht. Mittheilungen aus dem jahrbuche.

Ungarische geologische gesellschaft: Földtani közlöny.

Buenos Aires. Museo nacional: Anales.

Sociedad cientifica argentina: Anales.

Buffalo society of natural sciences: Annual meeting. Bulletin.

Caen. Laboratoire de géologie de la faculté des sciences: Bulletin.

Société linnéenne de Normandie: Bulletin.

California academy of sciences: Bulletin. Memoirs. Occasional papers. Proceedings.

Cambridge (Eng.) philosophical society: Proceedings. Transactions.

Canada. Geological and natural history survey: Annual report.

Canadian entomologist.

Canadian institute: Annual report. Transactions.

Cassel. Verein für naturkunde: Bericht.

Catania. Accademia gioenia di scienze naturali: Atti. Bullettino mensile.

Cellule.

Central park menagerie, New York: Report.

Centralblatt für physiologie.

Chambéry. Académie des sciences, belles-lettres et arts de Savoie: Documents. Mémoires.

Chemnitz. Naturwissenschaftliche gesellschaft: Bericht.

Cherbourg. Société des sciences naturelles: Mémoires.

Chicago academy of sciences: Transactions.

Christiania. Norske Frederiks universitet.

Norwegisches meteorologisches institut: Jahrbuch.

Videnskabs-selskabet: Forhandlinger. Oversigt over möder.

Chur. Naturforschende gesellschaft Graubündens: Jahresbericht.

Cincinnati society of natural history: Journal.

Clermont-Ferrand. Académie des sciences, belles-lettres et arts: Bulletin historique et scientifique de l'Auvergne.
Colmar. Société d'histoire naturelle: Bulletin.
Colorado scientific society: Proceedings.
Connecticut academy of arts and sciences: Transactions.
Cordova. Academia de ciencias: Actas. Boletin.
Cracovie. Académie des sciences: Bulletin internationale.
Danzig. Naturforschende gesellschaft: Neueste schriften.
Darmstadt. Verein für erdkunde: Notizblatt.
Davenport academy of natural sciences: Proceedings.
Dijon. Académie des sciences, arts et belles-lettres: Mémoires.
Dorpat. Gelehrte estnische gesellschaft: Sitzungsberichte. Verhandlungen.
Naturforscher-verein bei der universität: Archiv für die naturkunde Liv-, Ehst- und Kurlands. Schriften. Sitzungsberichte.
Dresden. Gesellschaft für natur- und heilkunde: Jahresbericht.
Naturwissenschaftliche gesellschaft Isis: Sitzungsberichte und abhandlungen.
Oekonomische gesellschaft im königreich Sachsen: Mittheilungen.
Verein für erdkunde: Jahresbericht.
Dürkheim. Pollichia: ein naturwissenschaftlicher verein der Rheinpfalz: Mittheilungen.
Edinburgh geological society: Transactions.
Elberfeld. Naturwissenschaftlicher verein. Jahresberichte.
Elisha Mitchell scientific society: Journal.
Elliott society of science and art: Proceedings.
Elmira academy of sciences: Proceedings.
Emden. Naturforschende gesellschaft: Jahresbericht.
Entomological news.
Entomological society of London: Transactions.
Entomological society of Ontario: Annual report.
Entomological society of Washington: Proceedings.
Entomologists' monthly magazine.
Erfurt. Akademie gemeinnütziger wissenschaften: Jahrbücher.
Erlangen. Physikalisch-medicinische societät. Sitzungsberichte.
Essex institute: Bulletin.
Feuille des jeunes naturalistes.
Field naturalists' club of Victoria: The Victorian naturalist.
Firenze. Società entomologica italiana: Bullettino. Resoconto delle adunanze generali e parziali.
Frankfurt a. M. Senckenbergische naturforschende gesellschaft: Abhandlungen. Bericht.
Frankfurt a. O. Naturwissenschaftlicher verein: Helios.
Frauenfeld. Thurgauische naturforschende gesellschaft: Mittheilungen.
Freiburg i. B. Naturforschende gesellschaft: Berichte.
Garden and forest.
Genève. Institut genevois: Bulletin. Mémoires.

Genève. Société de physique et d'histoire naturelle: Mémoires.
Genova. Museo civico di storia naturale: Annali.
Società ligure di storia patria: Atti.
Geographical club of Philadelphia: Bulletin.
Geological magazine.
Geological record.
Geological society of America: Bulletin.
Geological society of Glasgow: Transactions.
Geological society of London: Quarterly journal.
Gera. Gesellschaft von freunden der naturwissenschaften: Jahresbericht.
Giessen. Oberhessische gesellschaft für natur- und heilkunde: Bericht.
Görlitz. Naturforschende gesellschaft: Abhandlungen.
Oberlausitzische gesellschaft der wissenschaften: Neues lausitzisches magazin.
Göttingen. Gesellschaft der wissenschaften: Göttingische gelehrte anzeigen. Nachrichten.
Gotha. Justus Perthes' geographische anstalt: Petermanns mittheilungen.
Götheborg. Götheborgs vetenskaps och vitterhets samhället: Handlingar.
's Gravenhage. Nederlandsche entomologische vereeniging: Tijdschrift voor entomologie.
Graz. Naturwissenschaftlicher verein für Steiermark: Mittheilungen.
Verein der ärzte in Steiermark: Mittheilungen.
Greifswald. Geographische gesellschaft: Jahresbericht.
Groningen. Natuurkundig genootschap: Verslag.
Guernsey society of natural science and local research: Report and transactions.
Güstrow. Verein der freunde der naturgeschichte in Mecklenburg: Archiv.
Haarlem. Musée Teyler: Archives.
Société hollandaise des sciences: Archives néerlandaises des sciences exactes et naturelles.
Halle. Leopoldinisch-carolinische deutsche akademie der naturforscher: Leopoldina. Verhandlungen.
Naturforschende gesellschaft: Abhandlungen. Bericht.
Naturwissenschaftlicher verein für Sachsen und Thüringen: Zeitschrift für naturwissenschaften.
Verein für erdkunde: Mittheilungen.
Hamburg. Naturhistorisches museum: Mittheilungen.
Naturwissenschaftlicher verein: Abhandlungen.
Verein für naturwissenschaftliche unterhaltung: Verhandlungen.
Hanau. Wetterauische gesellschaft für die gesammte naturkunde: Jahresbericht.
Hannover. Naturhistorische gesellschaft: Jahresbericht.
Harvard university: Bulletin.

Harvard university. Astronomical observatory: Annals.
Heidelberg. Naturhistorisch-medicinischer verein: Verhandlungen.
Helsingfors. Finska vetenskaps societeten: Bidrag till kännedom af Finlands natur och folk. Ofversigt af förhandlingar.
Societas pro fauna et flora fennica. Acta. Meddelanden.
Societas scientiarum fennica: Acta.
Hermannstadt. Siebenbürgischer verein für naturwissenschaften: Verhandlungen und mittheilungen.
Verein für siebenbürgische landeskunde: Archiv. Jahresbericht.
Hertfordshire natural history society and field club: Transactions.
Ibis.
Igló. Ungarischer karpathen-verein: Jahrbuch.
Illinois. Geological survey: (Geology and palaeontology of Illinois.)
State entomologist: Report.
State laboratory of natural history: Bulletin.
India. Geological survey: Memoirs. Memoirs: palaeontologia Indica. Records.
Indian museum notes.
Indiana. Department of geology and natural history: Annual report.
Indiana academy of science: Proceedings.
Innsbruck. Ferdinandeum. Zeitschrift für Tirol und Vorarlberg.
Insect life.
Internationale monatsschrift für anatomie und physiologie.
Iowa. Geological survey: Annual report.
Iowa academy of sciences: Proceedings.
Italy. Comitato geologico d' Italia: Bollettino. Memorie per servire alla descrizione della carta geologica.
Jena. Medizinisch-naturwissenschaftliche gesellschaft: Denkschriften. Jenaische zeitschrift für naturwissenschaft. Sitzungsberichte.
Johns Hopkins university: Studies from the biological laboratory.
Journal de conchyliologie.
Journal de l'anatomie et de la physiologie.
Journal für ornithologie.
Journal of American folk-lore.
Journal of anatomy and physiology.
Journal of geology.
Journal of morphology.
Journal of mycology.
Just's Botanischer jahresbericht.
Kansas academy of science: Transactions.
Kansas state university: Annual report of the experiment station. Kansas university quarterly.
Karlsruhe. Verein für geschichte und naturgeschichte der Baar: Schriften.
Kazan university: Dissertations. Scientific memoirs.
Kew botanic gardens.
Kiel. Naturwissenschaftlicher verein für Schleswig-Holstein: Schriften.

Kiel. Universität: Chronik. Dissertations.
Kiew. Société des naturalistes: Mémoires.
Kingston school of mines.
Kjöbenhavn. Botaniske forening: Botanisk tidsskrift. Meddelelser.
Danske videnskabernes selskab: Naturvidenskabelige og mathematiske afhandlinger. Oversigt over det forhandlinger og dets medlemmers arbeider.
Naturhistoriske forening: Videnskabelige meddelelser.
Nordiske oldskrift-selskab: Nordiske fortidsminder. Tillaeg til aarböger for nordisk oldkyndighed og historie.
Klagenfurt. Naturhistorisches landesmuseum von Kärnten: Diagramme der magnetischen und meteorologischen beobachtungen. Jahrbuch.
Königsberg. Physikalisch-ökonomische gesellschaft: Beiträge zur naturkunde Preussens. Schriften.
Universität: Dissertations.
Lausanne. Société vaudoise des sciences naturelles: Bulletin.
Leeds philosophical and literary society: Annual report.
Leiden. Nederlandsche dierkundige vereeniging: Tijdschrift.
Leipzig. Fürstlich jablonowski'sche gesellschaft: Jahresbericht. Preisschriften.
Naturforschende gesellschaft: Sitzungsberichte.
Sächsische gesellschaft der wissenschaften: Abhandlungen der mathematisch-physischen classe. Berichte über die verhandlungen, math.-phys. classe.
Verein für erdkunde: Mittheilungen.
Le Mans. Société d'agriculture, sciences et arts de la Sarthe: Bulletin.
Library journal.
Liége. Société des sciences: Mémoires.
Société géologique de Belgique: Annales.
Lille. Société géologique du nord: Annales. Mémoires.
Linnaean society of New York. Abstract of proceedings. Transactions.
Linnean society of London: Journal; botany, zoology. Proceedings. Transactions; botany, zoology.
Linnean society of New South Wales: Proceedings.
Linz. Museum francisco-carolinum: Bericht.
Lisboa. Academia das sciencias: Jornal de sciencias mathematicas, physicas e naturaes.
Sociedade de geographia: Boletim.
Literary and historical society of Quebec: Transactions.
Literary and philosophical society of Liverpool: Proceedings.
Liverpool biological society: Proceedings and transactions.
Liverpool geological society: Proceedings.
Lucca. Accademia lucchese di scienze, lettere ed arti: Atti.
Lübeck. Geographische gesellschaft und naturhistorisches museum: Mitteilungen.
Naturhistorisches museum: Jahresbericht.

Lüneburg. Naturwissenschaftlicher verein: Jahreshefte.
Lund. Universitas lundensis: Ars-skrift, mathematik och naturvetenskab.
Luxemburg. Fauna: verein luxemburger naturfreunde: Mittheilungen.
Institut grand-ducal: Publications.
Lyon. Académie des sciences, belles-lettres et arts: Mémoires; sciences et lettres.
Société d'agriculture, d'histoire naturelle et des arts utiles: Annales des sciences physiques et naturelles, d'agriculture et d'industrie.
Société linnéenne: Annales.
Madrid. Sociedad geográfica: Boletin.
Magyar növénytani lapok.
Manchester literary and philosophical society: Memoirs and proceedings.
Mannheim. Mannheimer verein für naturkunde: Jahresbericht.
Marburg. Gesellschaft zur beförderung der gesammten naturwissenschaften: Schriften. Sitzungsberichte.
Marine biological association of the United Kingdom: Journal.
Marine biological laboratory, Wood's Holl, Mass.: Annual report.
Marseille. Musée d'histoire naturelle: Annales.
Maryland academy of science: Transactions.
Massachusetts. State board of agriculture: Annual report.
Trustees of public reservations: Annual report.
Massachusetts agricultural college: Bulletin of the Hatch experiment station.
Massachusetts horticultural society: Transactions.
Massachusetts institute of technology: Annual catalogue. Report Technology quarterly.
Mende. Société d'agriculture, industrie, sciences et arts du département de la Lozère: Bulletin.
Meriden scientific association: Transactions.
Metz. Société d'histoire naturelle: Bulletin.
Mexico. Deutscher wissenschaftlicher verein: Mittheilungen.
Museo nacional: Anales.
Sociedad científica Antonio Alzate: Memorias y revista.
Sociedad mexicana de geografía y estadistica: Boletin.
Sociedad mexicana de historia natural: La naturaleza.
Microscope.
Middelburg. Zeeuwsch genootschap der wetenschappen: Archief.
Milano. Istituto lombardo di scienze, lettere ed arti: Memorie, classe di scienze matematiche e naturali. Rendiconti.
Società italiana di scienze naturali: Atti.
Milwaukee public museum: Annual report.
Minnesota. Geological and natural history survey: Annual report. Bulletin.
Minnesota academy of natural sciences: Bulletin.
Missouri. Geological survey: Biennial report. Bulletin.
Missouri botanical garden: Annual report.

Modena. Accademia di scienze, lettere ed arti: Memorie.
Società dei naturalisti: Atti: memorie.
Società italiana delle scienze: Memorie di matematica e di fisica.
Monitore zoologico italiano.
Mons. Société des sciences, des arts et des lettres du Hainaut: Mémoires et publications.
Montevideo. Museo nacional: Anales.
Montpellier. Académie des sciences et lettres: Mémoires de la section des sciences.
Morlaix. Société d'études scientifiques du Finistère: Bulletin.
Morphologisches jahrbuch.
Moscou. Société des naturalistes: Bulletin. Nouveaux mémoires.
Moulins. Société d'émulation et des beaux arts de Bourbonnais: Bulletin-revue.
München. Bayerische akademie der wissenschaften: Abhandlungen der mathematisch-physikalischen classe. Almanach. Sitzungsberichte der mathematisch-physikalischen classe.
Münster. Westfälischer provinzial-verein für wissenschaft und kunst: Jahresbericht.
Museum of comparative zoology: Annual report. Bulletin. Memoirs.
Nancy. Académie de Stanislas: Mémoires.
Nantes. Société des sciences naturelles de l'ouest de la France: Bulletin.
Napoli. Accademia delle scienze fisiche e matematiche: Atti. Rendiconto.
Istituto d' incoraggiamento: Atti.
Zoologische station: Fauna und flora des golfes von Neapel. Mittheilungen. Zoologischer jahresbericht.
National academy of sciences: Memoirs.
Naturae novitates.
Natural history society of Glasgow: Proceedings and transactions.
Natural history society of Montreal: Canadian record of science.
Natural history society of New Brunswick: Bulletin.
Natural history society of Northumberland, Durham, and Newcastle-upon-Tyne: Natural history transactions of Northumberland, etc.
Natural history society of Wisconsin: Occasional papers. Proceedings.
Natural science.
Natural science association of Staten Island: Proceedings.
Naturalista siciliano.
Naturaliste.
Naturaliste canadien.
Nature.
Nautilus.
Neuchatel. Société des sciences naturelles: Bulletin.
Neues jahrbuch für mineralogie, geologie und palaeontologie.
New Jersey. Geological survey: Annual report.
New Jersey natural history society: Journal.

New South Wales. Department of mines: Annual report.
Geological survey: Memoirs, palaeontology. Records.
New York. State entomologist: Report on the injurious and other insects of New York.
State library: Annual report. Bulletin: additions, legislation, Library school.
State museum: Annual report. Bulletin. Memoirs.
State survey: Annual report. Report of the state geologist.
New York academy of sciences: Annals. Transactions.
New York meteorological observatory: Abstracts of registers.
New York microscopical society: Journal.
New Zealand. Colonial museum: Annual report. Reports of geological explorations.
Mining department: Report on mining industry.
New Zealand institute: Transactions and proceedings.
Newport natural history society: Proceedings.
Newton natural history society: Bulletin.
Nimes. Académie: Mémoires.
Norway. Norske gradmaalingscommission: Geodätische arbeiten. Vandstandsobservationer.
Nottingham naturalists' society: Transactions and annual report.
Nova Scotian institute of science: Proceedings and transactions.
Nürnberg. Naturhistorische gesellschaft: Abhandlungen. Jahresbericht.
Oberlin college laboratory: Bulletin.
Offenbach a. M. Offenbacher verein für naturkunde: Bericht.
Osnabrück. Naturwissenschaftlicher verein: Jahresbericht.
Ottawa naturalist.
Paris. Académie des sciences: Comptes-rendus.
Muséum d'histoire naturelle: Nouvelles archives.
Société botanique de France: Bulletin.
Société d'agriculture de France: Bulletin. Mémoires.
Société d'anthropologie: Bulletins. Mémoires.
Société d'horticulture de France: Journal.
Société de géographie: Bulletin. Comptes rendus.
Société des sciences naturelles de l'ouest de la France.
Société entomologique de France: Annales.
Société géologique de France: Bulletin. Compte-rendu.
Société philomathique: Bulletin. Compte-rendu.
Société zoologique de France: Bulletin.
Passau. Naturhistorischer verein; Jahresbericht.
Peabody academy of science, Salem: Annual report Memoirs.
Peabody institute, Baltimore: Annual report.
Peabody museum of American archaeology and ethnology, Cambridge: Annual report. Archaeological and ethnological papers.
Pennsylvania. Geological survey: Reports.
Philadelphia library company: Bulletin.

Philosophical society of Glasgow: Proceedings.
Philosophical society of Washington: Bulletin.
Phycological memoirs.
Pisa. Società toscana di scienze naturali: Atti, memorie. Atti, processi-verbali.
Popular science monthly.
Port-au-Prince. Société des sciences et de géographie.
Portland society of natural history: Proceedings.
Porto. Sociedad Carlos Ribeiro: Revista de sciencias naturaes e sociaes.
Portugal. Commission des travaux géologiques: Communicações.
Prag. Böhmische gesellschaft der wissenschaften: Abhandlungen, math.-phys. classe. Jahresbericht. Preisschriften. Sitzungsberichte.
Bohemian academy for arts, science and literature: Paleontographica Bohemiae. Proceedings: math.-nat. hist.
Naturhistorischer verein Lotos. Lotos: jahrbuch für naturwissenschaft.
Presburg. Verein für natur- und heilkunde: Verhandlungen.
Psyche.
Quarterly journal of microscopical science.
Queensland. Geological survey: Annual progress report.
Rassegna delle scienze geologiche in Italia.
Regensburg. Bayerische botanische gesellschaft: Denkschriften. Flora.
Naturwissenschaftlicher verein: Bericht.
Revue des sciences naturelles de l'ouest.
Revue scientifique.
Riga. Naturforscher-verein: Arbeiten. Korrespondenzblatt.
Rio de Janeiro. Instituto historico e geographico brazileiro: Revista trimensal.
Museu nacional: Archivos.
Rochester academy of science: Proceedings.
Roma. Accademia dei lincei: Atti, rendiconti.
Società romana per gli studi zoologici: Bollettino.
Rotterdam. Société batave de philosophie expérimentale: Nieuwe verhandelingen.
Royal Dublin society: Scientific proceedings. Scientific transactions.
Royal geographical society of London: Geographical journal.
Royal geological society of Ireland: Journal.
Royal horticultural society of London: Journal.
Royal institution of Cornwall: Journal.
Royal institution of Great Britain: Notices of the proceedings (proceedings).
Royal Irish academy: Cunningham memoirs. Proceedings. Transactions.
Royal microscopical society, London: Journal.
Royal physical society of Edinburgh: Proceedings.

Torino. Università: Osservazioni meteorologiche.
Torrey botanical club. Bulletin. Memoirs.
Toulouse. Académie des sciences, inscriptions et belles-lettres: Mémoires.
  Société d'histoire naturelle: Bulletin.
Tours. Société d'agriculture, sciences, arts et belles-lettres du département d'Indre-et-Loire: Annales.
Trieste. Museo civico di storia naturale: Atti.
  Società adriatica di scienze naturali: Bollettino.
Tromso. Tromso museum: Aarsberetning. Aarshefter.
Troyes. Société académique d'agriculture, des sciences, arts et belles-lettres du département de l'Aube: Mémoires.
Tufts college studies.
United States. Bureau of education: Circulars of information. Report of the commissioner.
  Bureau of ethnology: Annual report. Separates.
  Coast survey: Report.
  Department of agriculture: Farmers' bulletin. Report of the entomologist. Report of the microscopist.
    Bureau of animal industry: Bulletin.
    Division of entomology: Bulletin.
    Division of microscopy: Food products.
    Division of ornithology and mammalogy: Bulletin. North American fauna.
    Division of vegetable pathology: Bulletin. Report of chief of section.
    Entomological commission: Bulletin. Report.
  Fish commission: Bulletin. Report.
  Geological survey: Annual report. Bulletin. Mineral resources. Monographs.
  National museum: Annual report. Bulletin. Proceedings.
University of California: Bulletin of the department of geology.
University of Pennsylvania: Contributions from the botanical laboratory.
University of Tokio: Journal of the college of science.
Upsala. Universität: Bulletin of the geological institution.
  Vetenskaps-societeten: Nova acta.
Utrecht. Provinciaal utrechtsch genootschap van kunsten en wetenschappen: Aanteekeningen van het verhandelde in de sectie-vergaderingen. Verslag van het verhandelde in de algemeene vergadering.
Vassar Brothers' institute: Transactions.
Venezia. Ateneo veneto: Ateneo veneto.
  Istituto veneto di scienze, lettere ed arti: Atti. Memorie.
Verona. Accademia d' agricoltura, arti e commercio: Memorie.
Victoria. Department of mines: Annual report.
Victoria institute of Trinidad: Proceedings.

Wagner free institute: Transactions.
Wernigerode. Naturwissenschaftlicher verein des Harzes: Schriften.
West American scientist.
Wien. Akademie der wissenschaften: Denkschriften. Sitzungsberichte.
Central-anstalt für meteorologie und erdmagnetismus: Jahrbücher.
Gartenbau-gesellschaft: Wiener illustrirte garten-zeitung.
Geographische gesellschaft: Mittheilungen.
Geologische reichsanstalt: Abhandlungen. Jahrbuch. Verhandlungen.
Naturhistorisches hofmuseum: Annalen.
Verein zur verbreitung naturwissenschaftlicher kenntniss: Schriften.
Zoologisch-botanische gesellschaft: Verhandlungen.
Zoologisches institut der universität Wien und die zoologische station in Trieste: Arbeiten.
Wiesbaden. Nassauischer verein für naturkunde: Jahrbücher.
Wisconsin academy of sciences, arts, and letters: Transactions.
Wisconsin naturalist.
Würzburg. Physikalisch-medicinische gesellschaft: Sitzungsberichte. Verhandlungen.
Zoologisch-zootomisches institut: Arbeiten.
Yokohama. Deutsche gesellschaft für natur- und völkerkunde Ostasiens: Mittheilungen.
Yorkshire geological and polytechnic society: Proceedings.
Zeitschrift für biologie.
Zeitschrift für wissenschaftliche mikroskopie.
Zeitschrift für wissenschaftliche zoologie.
Zoe.
Zoological record.
Zoological society of London: Proceedings. Transactions.
Zoological society of Philadelphia: Annual report.
Zoologische beiträge.
Zoologische jahrbücher; abtheilung für anatomie und ontogenie, abtheilung für systematik, geographie und biologie.
Zoologischer anzeiger.
Zürich. Naturforschende gesellschaft: Vierteljahrsschrift.

REPORT OF THE TREASURER, EDWARD T. BOUVÉ.

ANNUAL STATEMENT, MAY 1, 1893 TO MAY 1, 1894. BOSTON SOCIETY OF NATURAL HISTORY.

Balance from April 30, 1893	$8,020.27	By cash paid on account of Repairs	$159.59
To cash received from Walker Prize and Special Expense Fund	869.45	" " " " " " " of roof. (N. E. Tel. and Tel. Co.)	674.76
To cash received from Walker Grand Prize Fund	126.60	By cash paid on account of General Expenses	964.87
" " " " " Fund Income for General Expenses	865.00	" " " " " " Fuel	208.93
To cash received from Bulfinch Street Estate Fund Income	1,195.13	" " " " " " Gas	41.65
To cash received from Courtis Fund Income	522.96	" " " " " " Insurance	773.00
" " " " S. P. Pratt Fund Income	533.24	" " " " " " Publications	1,000.00
" " " " H. F. Wolcott Fund Income	406.95	" " " " " " Library	1,031.95
" " " " C. L. Flint Fund Income	150.29	" " " " " " Museum and Cabinets	277.21
" " " " Entomological Fund Income	26.08	" " " " " " Boston Museum Collection	752.24
" " " " J. W. Randall Fund Income	125.00	" " " " " " Salaries and Wages	6,666.99
" " " " Dividends and Income	5,071.84	Balance to new account	1,729.62
" " " " Admission Fees	114.00		
" " " " Annual Assessments	1,254.00		
Total,	$14,280.81	Total,	$14,280.81

REPORT OF THE TREASURER, EDWARD T. BOUVÉ

Annual Statement, May 1, 1893 to May 1, 1894. Boston Society of Natural History

To cash received from Trustees W. J. Walker Estate.....	$10,[illegible]	By cash paid for $1,000 Burlington and [illegible] R. R. Bonds	$1,[illegible]
" " " " sundry persons; Special Museum Fund........	[illegible],117.85	" " " S. P. Pratt Fund Balance invested	[illegible]
To cash received, donations........	98.00	" " " exchanging Old Colony R. R. Stock	[illegible]
" " " Walker Grand Prize Fund. Bank stock retired........	400.00	" " " Trustees Walker Prize and Grand Prize Funds, deposited........	[illegible]
To cash received, S. P. Pratt Fund. Bank stock retired.	400.00	Balance on hand for investment........	[illegible]
" " " Entomological Fund. Bank stock retired........	[illegible].00		
	$13,[illegible]		$[illegible]

To cash received from Augustus Lowell, Trustee for the Teachers' School of Science........	$2,300.00	By cash paid for lectures and supplies........	$2,[illegible]
		Balance to new account........	[illegible]

To cash received from Boston University........	$2,[illegible].00	By cash paid for lectures and materials*....	$[illegible]

* A part of the amount paid on account of the Laboratory Lectures is charged to Salaries and Wages.

The Auditing Committee reported that the examination of the accounts of the Treasurer for the past year showed them correct with proper vouchers for all payments; that the securities in the hands of the Trustees agreed with the ledger balances and that the receipts and disbursements of the Garden Fund were believed to be correct.

It was voted to accept and place on file the several reports.

After opening the envelope accompanying the Walker Prize essay, Mr. W. O. Crosby was announced as the author of the paper on the Blue Hill complex and the recipient of the prize awarded by the committee.

The Society then proceeded to ballot for officers for 1894–95.

Messrs. W. M. Davis and J. Walter Fewkes were appointed a committee to collect and count the votes. They reported twenty-five ballots cast, a majority being for the candidates nominated.

OFFICERS FOR 1894-95.

The (*) indicates election at this meeting.

PRESIDENT,

*WILLIAM H. NILES.

VICE-PRESIDENTS,

*SAMUEL WELLS. *NATHANIEL S. SHALER.
*WILLIAM G. FARLOW.

CURATOR,

*ALPHEUS HYATT.

SECRETARY,

*SAMUEL HENSHAW.

TREASURER,

*EDWARD T. BOUVÉ.

LIBRARIAN,

*SAMUEL HENSHAW.

COUNCILLORS FOR THREE YEARS,

*S. L. Abbot.
*William S. Bryant.
*William M. Davis.
*J. Walter Fewkes.
*Edward G. Gardiner.
*Henry W. Haynes.
*Miss Catherine I. Ireland.
*Benjamin Joy Jeffries.

COUNCILLORS FOR TWO YEARS,

George H. Barton.
William Brewster.
Miss Cora H. Clarke.
Robert T. Jackson.
Nathaniel T. Kidder.
Edward S. Morse.
William T. Sedgwick.

COUNCILLORS FOR ONE YEAR,

William A. Jeffries.
Augustus Lowell.
Miss Susannah Minns.
John Ritchie, Jr.
Alfred P. Rockwell.
Charles S. Sargent.
Henry F. Sears.
Thomas A. Watson.

COUNCILLORS *ex-officiis*,

Thomas T. Bouvé.
John Cummings.
George L. Goodale.
F. W. Putnam.
Samuel H. Scudder.

The following papers were read :—

ON THE SYSTEMATIC POSITION OF THE SIPHONAPTERA, WITH NOTES ON THEIR STRUCTURE.

BY ALPHEUS S. PACKARD.

This paper is based on the researches and conclusions of Landois, Kraepelin, and Wagner, besides some fragmentary drawings and notes of my own. In former years I was quite of the opinion of Haliday that the fleas were a group of Diptera

allied to the Mycetophilidae, but after a careful reading of Kraepelin's able memoir, and a reconsideration of the whole subject, I have for several years past been led to believe that they should be referred to an independent order, with closer affinities to the Diptera on the whole, however, than to any other order.

It may be well to review briefly the history of opinion as to the position of the fleas in the class of insects, and which is taken in part from the memoirs of Dr. O. Taschenberg and of Dr. Karl Kraepelin. The authors who placed them among the Aptera were Linnaeus, Geoffroy, Cuvier and Duméril, and Gervais. Kircher referred them to the Orthoptera.

Those who regarded them as Diptera were Roesel, Oken, Straus-Dürkheim, Burmeister, Haliday, Newman, Walker, von Siebold, with many German entomologists, and J. Wagner (1889).

They were regarded as Hemiptera by Fabricius and by Illiger.

The fleas were regarded as the types of a distinct order by DeGeer, Lamarck, Latreille, Kirby and Spence, MacLeay, Leach, Dugès, Bouché, van der Hoeven, Westwood, Landois, Brauer, and Taschenberg, besides Kraepelin.

The fleas were placed by MacLeay and by Balbiani between the Diptera and Hemiptera; by Leach between the Hemiptera and Lepidoptera; by Dugès between the Hymenoptera and Diptera; and by Brauer they are given a position between the Diptera and Coleoptera.

Comparison of the Embryonic Stages with those of the Diptera.

Thus far the studies made on the embryology of insects of different orders have elicited no characters of special taxonomic importance. The differential characters of the insect orders are largely adaptive, and were evidently evolved in postembryonic life. There seems to be much similarity between the embryos of the metamorphic orders, Coleoptera, Lepidoptera, Siphonaptera, Diptera, and Hymenoptera.

In his elaborate work on the embryology of the Diptera, Weismann[1] describes and figures a single stage in the develop-

[1] Die entwicklung der dipteren. Zeitschr. für wiss. zool., 13, 1863.

ment of *Pulex canis*, and remarks that "at the first glance the great similarity with the embryo of the Tipulidae is apparent," and farther on, "while also the form and position of the primitive band wholly correspond to their relations in Chironomus, so also the composition of each segment is wholly analogous. . . . The number of primitive segments agrees with that of the Tipulidae, and the last (twelfth) segment is clearly seen to be due to the union of two pieces pressed together, one dorsal and the other ventral, between which a fine pointed prolongation of the yolk projects, just as is the case in the same stage of Chironomus (Taf. 3, fig. 32). . . . We need only state that the embryonal development of the flea comes nearest to that of the Tipulidae, that the two families belong to those insects which are developed out of a primitive band, which owes its origin to a splitting of the blastoderm" (p. 89, 90).

In his article on the embryology of *Pulex felis* Balbiani notices the appearance of rudiments of the thoracic feet, though the larva is hatched in an apodous condition. (Comptes rendus, 1875.)

In our brief essay on the development of *Pulex canis*[1], we were also struck by the resemblance of the embryo in its different stages to that of Chironomus. And yet on reconsidering the matter, the resemblance of the embryo of the flea to that of certain Coleoptera (Attelabus, Telephorus, Chrysomela, etc.), appears to be nearly as strong, and perhaps when farther researches are made on the embryology of the Siphonaptera, some points of resemblance may be elicited.

The Freshly Hatched Larva.

Fig. 1 represents a larva just ready, Nov. 9, to hatch, the egg having been laid Nov. 3. Just before hatching the embryo grows much longer, and the larva lies coiled up in the egg, with the head, however, free from the coil.

The young larva is very transparent, the digestive canal, heart, and nervous system being readily distinguishable, while the spiracles and tracheae were not observed. In Fig. 1 the heart (*h*) is seen to form a long slender tube, which was traced as far as the posterior part of the head, nearly reaching the back part of

[1] Memoirs Peabody acad. sci., Salem, Mass., 1872.

the brain, and posteriorly it is seen to end in the penultimate segment of the body.

The brain (Fig. 1, *br*) or supraoesophageal ganglion forms a large rounded mass situated nearly midway between the front and posterior end of the head. The suboesophageal ganglion (*soe.g*) is but little smaller than the brain and lies directly below,

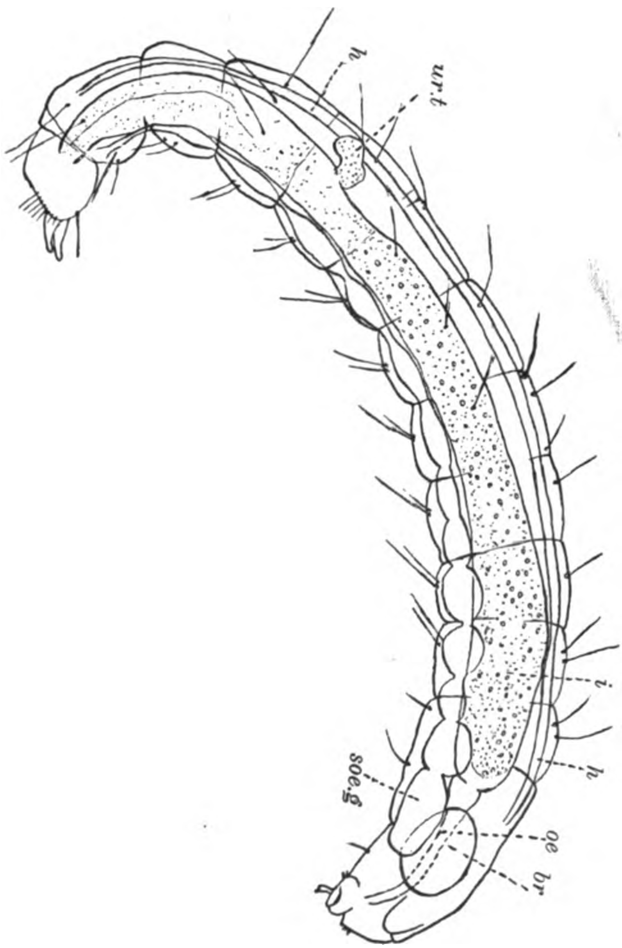


FIG. 1. Larva of *Pulex canis* just before hatching and removed from the egg; *br*, brain; *soe.g*, suboesophageal ganglion; *oe*, oesophagus; *h*, heart; *i*, digestive canal; *ur.t*, rudiment of an urinary tube.

and a little behind it. Succeeding this pair of ganglia are 11 or 12 ganglia, or one to each segment, except the last two abdominal ones.

The oesophagus is seen to be long and slender. The slight enlargement at the end is, however, the incipient proventriculus. The rest of the alimentary canal at this stage has not yet been differentiated into stomach and intestine, but begins at the posterior end of the head and continues to the end of the body as a larger thick tube of the same size throughout its length.

The completely formed digestive tract is seen in Fig. 2, representing an older larva drawn and presented to me by the late Edward Burgess. The oesophagus is now seen to pass near the hinder end of the 1st thoracic segment into a small spherical proventriculus. The true stomach extends to near the posterior third of the body, as far as the 9th segment behind the head, while the slender intestine is represented as twice bent upon itself, first in the penultimate segment, and a second time at a point in front under the suture between the 9th and 10th segments.

In Mr. Burgess's drawing (Fig. 2), no salivary glands are represented, neither are they by Bonnet, and I am inclined to think that they are wanting.

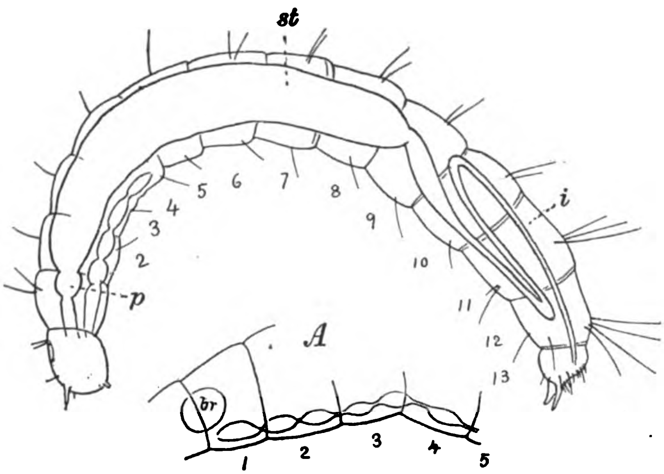


Fig. 2. Larva of *Pulex canis*; *p*, proventriculus; *st*, stomach; *i*, intestine; *A*, *br*, brain, and six succeeding ganglia.—*Burgess del.*

The urinary tubes are not represented by Burgess nor by Bonnet, but I am inclined to think that there is at least a pair of them,

judging from my figure of what are apparently two diverticula of the posterior third of the digestive tract in the larva when ready to hatch (Fig. 1, *ur.t.*). Mr. Burgess in his notes states that he made out spiracles "on every segment but the first three," but the one on the last segment was marked doubtful, and I have erased it from his drawing, as no insect larvae are known to have a pair of spiracles on the last segment.

The egg-shell burster.—This is an interesting example of the development of a temporary larval structure, and so far as known is a solitary instance of such a structure in insects. The only other cases known to me among the Arthropoda are the egg-

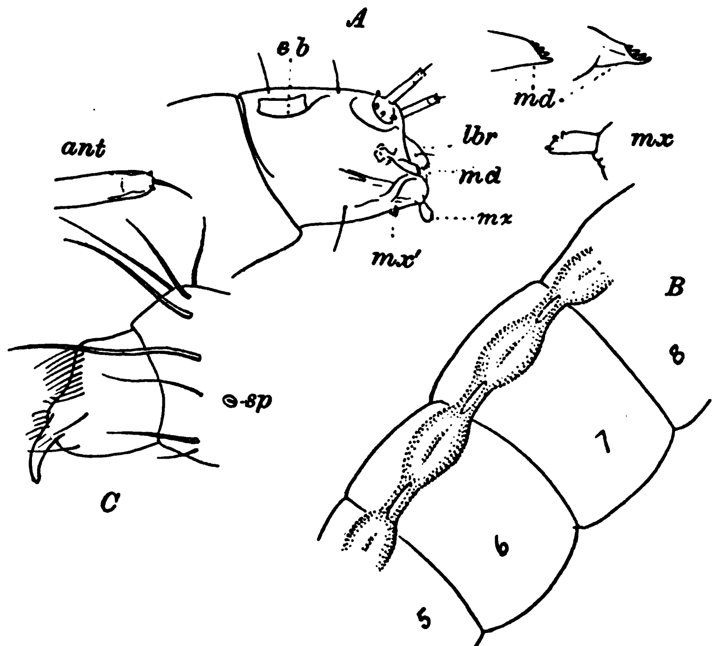


FIG. 3. Details of larva of *Pulex canis; A, eb,*egg-breaker; *lbr,* labrum; *mx,* maxilla; *mx',* labium; *md,* right and left mandibles; *ant,* antenna; *B,* 5–8 segments behind the head showing the ganglia; *C,* end of the body, *sp,* last pair of spiracles, with the caudal stylets.—*Burgess del.*

shell burster or boring apparatus on the embryonal cuticle over the head of the diplopod myriopod, *Strongylosoma guerinii*, and on the third pair of mouth-parts of Geophilus, figured and

described by Metschnikoff[1]; and an analogous structure on the cephalothorax of the embryo of phalangids observed by Balbiani.

The egg-shell burster of *Pulex canis* (also observed by Künckel, and afterwards by Balbiani) was seen in the egg just before hatching. It is a thin vertical plate like the edge of a knife, situated in the median line of the head very near the posterior end and is of the form represented in Figs. 3 and 4, being somewhat cultriform, the upper edge slightly hollow, the anterior end being slightly turned up. Unfortunately the apparatus was not seen in motion, nor the muscles moving it, if any such exist. So far as I could see, it is a fixed chitinous, keel-like spine which, however, was not seen to rise above the surface of the head, though it is evident that it is situated at just the point on the head where it would come in contact with the egg-shell, and it was evident that the larva, by rubbing its head back and forth, would produce a slight split in the shell, and cause it to burst asunder.

In the larva just before hatching the plate is no more hard and chitinous than the rest of the head, but in another larva a little older it was harder and with more chitine than in the rest of the head.

It will be seen by Burgess's figure that he also perceived this structure, and represents the upper edge as slightly hollow. He drew no muscle. The organ was previously observed but not represented by Bonnet in his figure of the larva of Sarcopsylla.

Later on in larval life it probably disappears, possibly after the first molt, though we know nothing of the process and number of molts in the fleas.

The general shape of the head is more like that of Gyrinus, Philhydrus, etc., than of the Mycetophilidae or other dipterous larvae, being conical, longer than broad, and on the under side the mentum or mental region is large, extending back to near the end of the head and forming a long scutellate area.

There are no traces of eyes. The labrum is large and of the normal shape, rounded in front.

The antennae (Fig. 4, 5, *ant*) are three-jointed, rather long and slender, being about one third as long as the head. On the short basal joint, surrounding the base of the long, rather thick, second joint are six short spinules; the third joint is very slender,

[1] Zeitschr. für wiss. zool., 24, p. 263, taf. 25, f. 18, 19, 1873; ibid, 25, taf. 20, f. 7, u. taf. 21, f. 11, 12, u, 1875.

like a blunt hair, and only as long as the second joint is thick. The mouth-parts are composed of a well-developed pair of mandibles, while the maxillae, especially those of the second pair, are quite rudimentary.

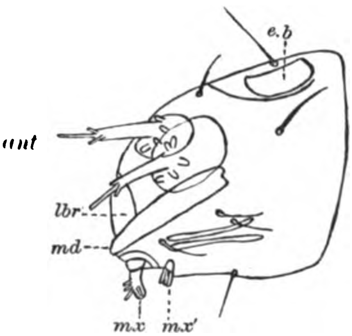


FIG. 4. Head of freshly hatched larva of *Pulex canis*; *e.b*, egg-breaker; *ant*, antennae; *md*, mandible; *mx*, maxilla; *mx'*, 2d maxilla (labium).—*Author del.*

The mandibles (Fig. 3, 5, *md*) seen from the side are broad, triangular, ending in two teeth, but in a partly profile view are seen to end in five rounded teeth. Compared with those of other larvae, they are more like those of coleopterous larvae than dipterous, being less modified and degenerate than in the latter.

The maxillae (Figs. 3–6, *mx*) are somewhat reduced, not divided into an inner and outer lobe as in the eucephalous dipterous larvae, being represented by a two-jointed appendage, about half as long as the antennae. The distal joint is a little over twice as long as the basal one, and is

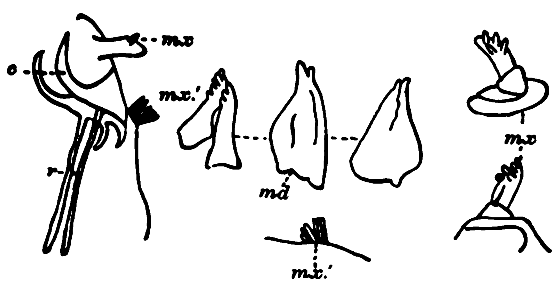


FIG. 5. Mouth-parts of freshly hatched larva of *Pulex canis*; *mx*, maxilla; *c*, maxillary capsule; *r*, styles or rods for attachment of the retractor muscles; *md*, mandibles from different sides; *mx'*, teeth arising from the labium or second maxillae.—*Author del.*

thick, rounded at the end, and bears just within the extremity on the inner edge two rows of stout, blunt spinules, the inner of the two rows being composed of four spinules. Each maxilla is

supported by a large, curved, chitinous, incomplete ring (the homologue of the *kieferkapsel* of Brauer) enclosing the base of the first maxillary joint, the lower portion of the ring expanded triangularly, and sending out laterally a slender curved hook. From this apparatus two parallel, long, slender, chitinous rods pass backward, ending near the middle of the head, and forming the support of the muscles extending and retracting the maxillae.

The second maxillae (Figs. 3–5, mx^1) have undergone much reduction, and are very minute. They are united at the base as usual to form the labium, and each division ends in three slender spinules. In their minute size, rudimentary shape, the entire labium ending in six spinules or slender teeth, the 2d maxillae more closely resemble those of certain eucephalous dipterous larvae than those of the Coleoptera or any other group.

The caudal stylets (Figs. 1, 3, *C*) are strong, recurved, chitinous structures which prop up the body of the larva in creeping or wriggling over the surface, and remind us of similar props in the larvae of the scavenger Coleoptera. We know of no similar structure in dipterous larvae. They are evidently adaptational outgrowths and of little morphological or taxonomic significance.

Comparison of the Larva with those of the Diptera.

The larvae of the Pulicidae have been usually likened to those of the eucephalous Diptera, together with those of the Mycetophilidae, rather than to those of any other order, and yet in some respects they are nearly as much like those of certain Coleoptera as those of the Diptera.

External anatomy.—In comparing the head of a Pulex larva with that of a Gyrinus it will be seen that the under side of the head of the former is very similar to that of Gyrinus and other coleopterous larvae in the perfection, and especially in the definite larger scutellate mental and gular region, which extends posteriorly to near the hinder edge, as shown in Fig. 6, *B*, *mt*. This region is not apparently developed in the dipterous larvae, owing to the extensive modification of the head. In other respects there is no special resemblance between the larvae of the Pulicidae and those of Coleoptera.

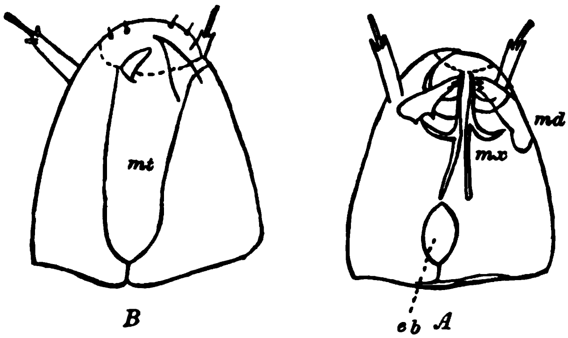


FIG. 6. *A*, dorsal view of head; *eb*, egg-breaker; *B*, ventral view, showing the mental and gular region.

In comparing the larvae of fleas with those of the Diptera[1] it is to be observed at the outset that the former are less modified than the latter. The shape of the head in general and its parts have on the whole undergone less extreme modification in the fleas than those of any Diptera, even the most generalized of the *Diptera eucephala*.[2]

The Diptera, both as regards their larval and imaginal characters, have apparently undergone a greater degree of modification than any other order of insects, and this extreme degree of adaptation and modification is exhibited especially in the larvae. There seems to be no ancestral, generalized larval type of the order in existence. The head and its appendages have undergone in response to adaptation to their unusual environment, most of the forms being aquatic, a greater or less reduction, not only in the mental and gular region, but in the appendages. So great is this reduction and modification, especially of the head and its appendages, that it is almost impossible to conjecture from which of the lower orders the Diptera have descended. We

[1] For an excellent account and figures of the higher dipterous larvae I am indebted to Meinert's admirable work, Sur les larves eucéphales des diptères. Vidensk. sels. skr., 1886. Also Brauer's valuable work cited below.

[2] Brauer's tribe 1, *Eucephala*, embraces those dipterous larvae with a completely differentiated head, which contains the first pair of ganglia and sometimes the eyes. It includes the following families: Mycetophilidae, Bibionidae, Chironomidae, Culicidae, Blepharoceridae, Simulidae, Psychodidae, Ptychopteridae, and Rhyphidae. Systematische studien auf grundlage der dipteren-larven nebst einer zusammenstellung von beispielen aus der litteratur über dieselben und beschreibung neuer formen. Wien, 1883.

have no such clew to their ancestry as is afforded in the Lepidoptera by the lower Tineina, such as Micropteryx, which is not far removed from the Trichoptera, and we have no such strong analogies to the larval Mecoptera (Panorpidae) which suggest that forms like them may have given rise to the Lepidoptera. The Diptera thus stand off by themselves as a side branch of the insect class; though it should be borne in mind that the larvae and pupae, especially the latter, of lepidopterous, dipterous, and hymenopterous insects are more closely related than those of other orders. The mouth-parts of the larval Siphonaptera are not apparently formed on the dipterous type, so to speak, though the primitive or ancestral forms of larval dipterous mouth-parts are not now perhaps to be found.

The antennae present no characteristic difference from coleopterous and dipterous larvae.

The mandibles are naturally of little taxonomic value in any group, since they are so obviously adapted to the nature of the food, but in the larval fleas they are perhaps of a more generalized nature than in any of the Diptera. The Mycetophilidae appear on the whole, unless the Cecidomyiidae and Bibionidae, of whose mouth-parts we know nothing, be excepted, to have the most perfectly formed head. But the mandibles as described and figured by Osten Sacken[1] are much more rudimentary than those of the young flea, which in general shape nearest approach those of Tanypus (Fig. 7).

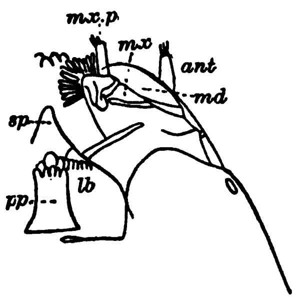


FIG. 7. *Tanypus varius; mx*, maxilla; *lb*, labium; *pp*, pharyngeal plate; *sp*, spinneret; *md*, mandible; other lettering as in previous figures.—*After Meinert.*

The maxillae of the larval *Diptera eucephala* are said by Meinert to have in general but a single large lobe; they are, however, two-lobed in Culex, Dixa (Fig. 8), and Simulium (Fig. 9); the "outer lobe" of Meinert (lacinia) is the larger; the inner, the galea, is the smaller and armed with bristles in Culex. The maxillary palpi except in Ceratopogon are always distinct, often cylindrical, prominent, and attached to a palparium. In Simulium the palpus is two-jointed.

Osten Sacken describes the max-

[1] Proc. ent. soc. Phil., 1, p. 151, pl. 2.

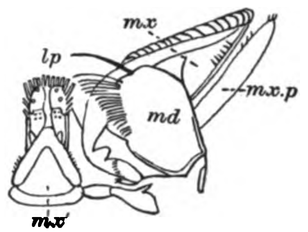


FIG. 8. Maxilla of *Dixa*; *lp*, labial palpi (?) or end of labium.—*After Meinert.*

illae of the Mycetophilidae as provided "with a large coriaceous inner lobe, and a horny outside piece, with a circular excision at the tip." The inside piece (galea) is dentate on the inner edge. On the outer lobe in Sciara is what Osten Sacken describes as "a small fleshy tubercle," and which "is evidently a rudimentary maxillary palpus." The palpus is best developed in Sciophila, "where it is subuliform and apparently two-jointed." It thus appears that the maxillary palpi are better developed in Dixa and Simulium than in any other dipterous larvae. There seems, then, to be no special resemblance between the maxillae of siphonapterous and dipterous larvae.

It thus appears that in those dipterous larvae with the most generalized mouth-parts, the galea, lacinia, and palpus with its palparium are well developed; hence they are on nearly the same plane as the Neuroptera.

The labium or 2d maxillae of the larval *Diptera eucephala* are described by Meinert as being always without palpi, and as existing in the form of a very corneous plate toothed on the anterior edge. In Culex the labium is broad, triangular, with numerous fine teeth. In Chironomus the teeth are few and large. In the larva of *Pulex canis* the labium is very minute, much reduced, and though I did not work out its actual shape, especially its base,

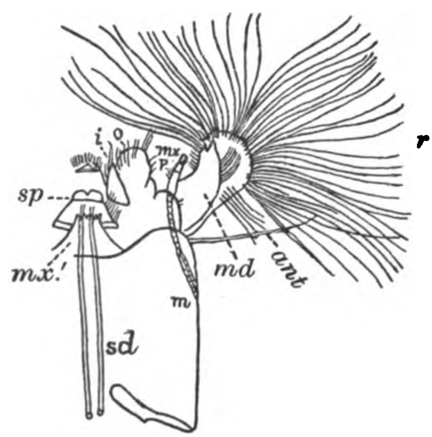


FIG. 9. Mouth-parts of Simulium; *sp*, spinneret; *sd*, salivary ducts; *o*, outer, *i*, inner lobe of maxilla; *mxp*, maxillary palpus; *r*, rotating organ of mandible (*md*); *ant*, bristle-like antenna.—*After Meinert.*

yet as seen in Figs. 4 and 5 it ends in six long slender spinules, the three on each side slightly diverging from the three on the other. Its shape when carefully worked out will probably be found to be not much unlike that of the labium of Dixa (Fig. 8), Simulium and Tanypus (Fig. 7).

Except in the form of the labrum, and the general vermiform appearance of the body, the larva of the Siphonaptera does not externally closely resemble the shape of the dipterous larvae, though indeed as much like them as those of any other metabolic order of insects.

Internal anatomy.—It is to be noted that in the freshly hatched larva of *Pulex canis* both the brain and infraoesophageal ganglia are contained within the head.

Brauer attaches great importance to the position of the brain in dipterous larvae, remarking: "As hereditary and typical for the entire great group of dipterous larvae appears to be the position of the head-ganglia, whether they lie in a head-capsule, or are free, situated far behind the mouth-opening, or directly behind the maxillary capsule which supports the mouth-parts and encloses the oesophagus" (p. 4). He then mentions as one of the most important characters of the *Diptera eucephala*, the fact that the first ganglion (brain) is contained in a completely differentiated head.[1]

We see (Fig. 1) that in the larval Pulex not only is the head itself more perfectly formed than in any dipterous larva, but also both the brain or supraoesophageal, and the infraoesophageal, ganglia are contained within the head. It is, however, possible that later on in larval life they may move backwards and lie partly within the segment next behind the head.

The absence of salivary glands is another point in which the larvae of the Siphonaptera differ from those of the flies.

[1] Osten Sacken criticizes this statement of Brauer, remarking that it needs confirmation, and he refers to the statement of Miall and Hammond that the larval head of Chironomus "contains no brain," although this genus belongs to the Eucephala. (Berlin. ent. zeitschr., 1892, p. 445, 463.) Compare also the work of Weismann, Die entwicklung der dipteren, 1863, wherein is figured the brain or 1st ganglion of Chironomus, which in the embryo is situated behind the head and even behind the prothoracic pair of false legs, though the head is as wide as the body. (Taf. 4, fig. 44, 46, 51.) Miall also states (Trans. ent. soc. Lond., 1893, p. 241) that in the larva of a tipulid fly, *Dicranota bimaculata*, "none of the ganglia lie in the head. The brain, with the suboesophageal and prothoracic ganglia, lies in the fore part of the mesothorax; the mesothoracic ganglion occupies the hinder part of the same segment."

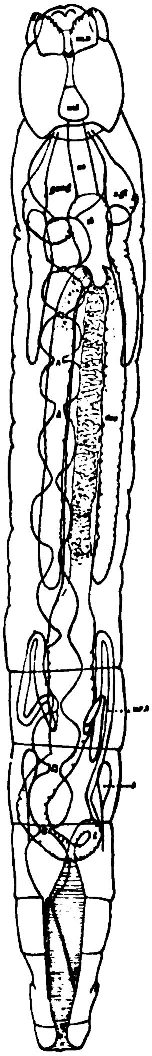


FIG. 10. Larva of *Sciara*; *s.gl*, salivary gland; *ur.t*, urinary tubes; *i*, intestine; *st*, stomach; *coe*, coecal appendages; *t*, testis? —*Author del.*

In dipterous larvae they are present according to Dufour[1], who describes and figures them in Tipulidae (*Tipula lunata* and *Pachyrrhina maculosa*), also in the Mycetophilidae (Mycetophila and Ceroplatus. See also my figure of a mycetophilid larva, Sciara[2], Fig. 10), in the Asilidae and the Oestridae (*Hypoderma bovis* and *Oestrus equi*). Hence they probably exist in nearly if not quite all dipterous larvae.

The spherical proventriculus of the larva of Pulex is much as in dipterous larvae (Tipula and Oestrus).

So far as is known there are no coecal appendages of the stomach in the larval Siphonaptera, though Dufour figures them in the larva of Tipula, where there are four small ones; and in the larva of Sciara I have found a pair of very large ones nearly one third as long as the body (Fig. 10, *coe*). In this larva I could easily see the contents of the two coeca passing into the intestine, and oscillating back and forth.

It thus appears that by the external and internal structure of the larvae, the Siphonaptera, though presenting superficially a close resemblance to the larval Diptera, those of both groups being apodous, and with elongated bodies, yet differ in important characters, and we may agree with Kraepelin, who remarks: "The larvae of the two groups at first sight look so much alike and indeed to such an extent that Brauer without hesitation made a distinct group (*einordnung*) of the larvae of fleas in his group of orthoraphheucephalous dipterous larvae. But on the other hand, it should not be forgotten that

[1] Recherches anatomiques et physiologiques sur les diptères. Mémoires mathémat. des savants étrangers, Paris, 1851. Separately printed, Paris, 1850.

[2] Kindly identified as a species of Sciara by Osten Sacken, from a tracing of the head of my sketch.

there are maggot-like larvae in groups standing far apart from the dipterous type, among Hymenoptera and Coleoptera, and therefore this should probably not be decisive in settling the question as to the relations of the fleas to the Diptera."

Comparison of the pupa of fleas with that of Diptera.—Kraepelin states that the pupa of the flea with its limbs entirely free differs so much from the fundamental type of non-coarctate mummy pupae that one author (Dugès) has already attempted on these grounds to construct a relationship of the fleas with the Hymenoptera.

The absence of any rudiments of wings in the pupa of the flea is characteristic of this order, those of Diptera being in many cases provided with the rudiments of both pairs, much as in lepidopterous pupae.

This subject needs working over, for the rudiments may yet be found; and the imaginal discs should be sought for in the larva. Perhaps the result of such studies will throw some additional light on the relations of the Siphonaptera to the Diptera.

Comparison of the Imago Stage of Siphonaptera with that of Diptera.

In comparing the structure of the adult Siphonaptera with that of the Diptera we shall have to rely on the work of Kraepelin, who justly claims that a study of the mouth-parts of the two groups, as well as that of the thorax and its appendages, will alone enable us to arrive at a decision of the question in dispute; also on the later researches of Wagner. We will first give an abstract of Kraepelin's researches. While, he says, the unpaired organ of the mouth-parts is the labrum (he also calls it the epipharynx), which is the homologue of that of the Diptera, the same cannot be said of the other components of the sucking tube of the two groups.

The hypopharynx, present in all Diptera, is found also in the Pulicidae.

There are also great differences in the structure and physiological uses of the flea's beak, as compared with that of the fly.

A labium extending, as in Diptera, unpaired the whole length, and provided at the end with a one-jointed terminal lip (endlippen)

does not occur in the Pulicidae, although something like it was until recently asserted to exist in Sarcopsylla. That of this genus has two-jointed palpi, and indications of a farther segmentation, so that in this respect it is as in other Pulicidae. This difference in

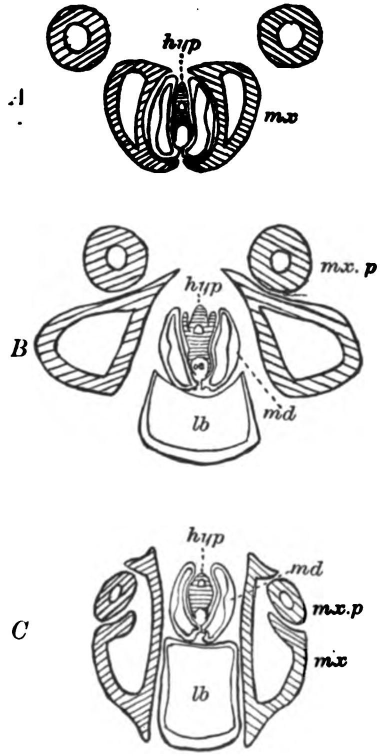


FIG. 11. Transverse sections through the mouth-parts of *Pulex; A*, section through the anterior third of the beak of *P. irritans; B*, through the basal third of the beak of *P. serraticeps; hyp*, hypopharynx; *md*, mandible; *mx*, maxilla; *mp*, maxillary palpi; *lb*, labium; *mx.'p*, labial palpi; *oe*, oesophagus; *sd*, salivary duct, (the perforation in the hypopharynx); *C*, through the base of the same.—*After Kraepelin*.

the segmentation of the labium of fleas as compared with Diptera, which is accompanied by a typical difference in the relation of the length of the unpaired basal parts to the paired portion, like palpi to the section designated, is phylogenetically not remarkable from the fact that the under lip of the Diptera has an entirely

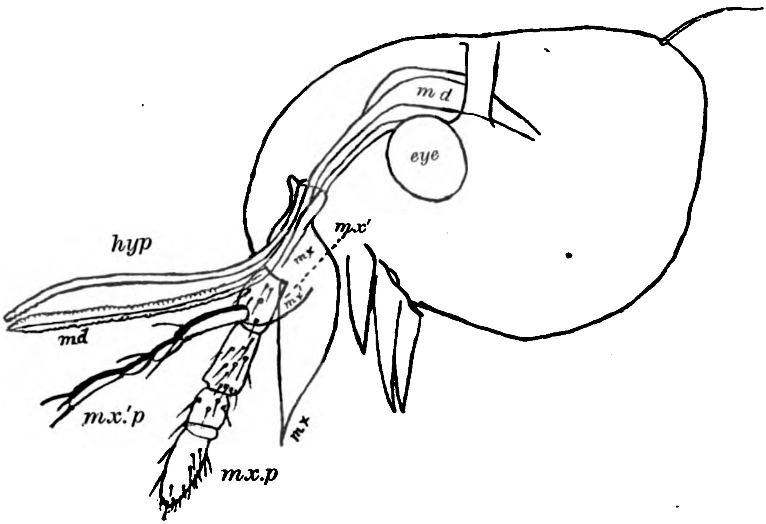


FIG. 12. Head of *Pulex canis* ♀; most of the spines omitted; *hyp*, hypopharynx; *mx'*, second maxilla, or labium; *mx.'p*, second maxillary palpi (antennae omitted).

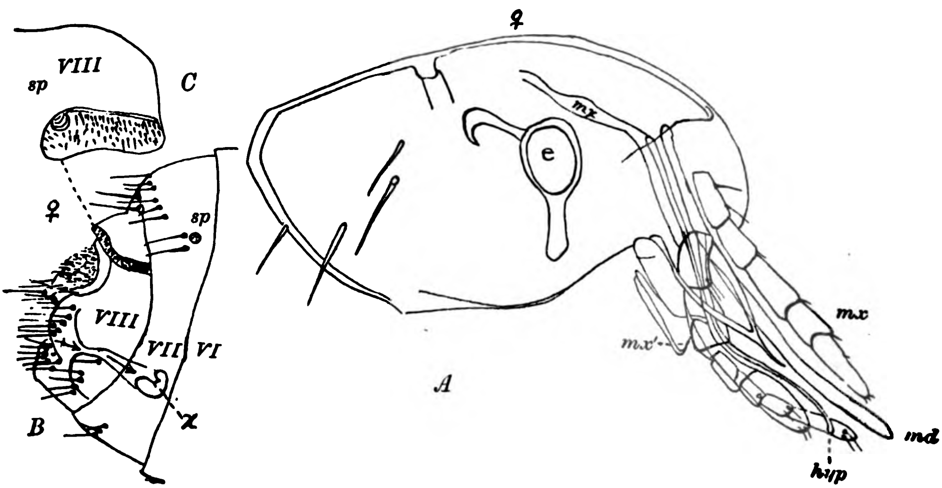


FIG. 13. *A*, head of *Pulex canis* ♀ (antennae omitted); *B*, the last two segments of the body, VII, VIII, in the lower part of the 7th segment is a kidney-shaped organ (*x*) not seen in ♂; *C*, edge of tergal portion of 8th segment, with the 8th spiracle (*sp*) enlarged.

different mode of union with the head, and thus physiologically is turned to an entirely different purpose from that of Diptera.

In the Diptera the maxillae as well as the labium are attached, together with the under lip, to the head, by a broad base; but in fleas such a union of the labium with the head is wanting. It is

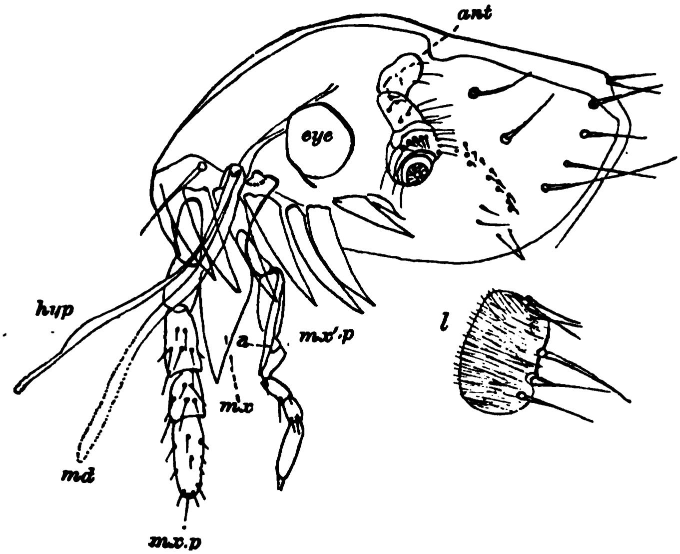


FIG. 14. Head of *Pulex canis* ♂; *l*, an area on middle of the side of 1st abdominal segment in ♂ and ♀, covered with numerous very fine appressed hairs.

articulated by a firm, brown, chitinous piece in the median line of the under side of the head, and this union is so loose that it has been doubted whether the Sarcopsyllidae have a complete labium. It forms, in this group, however, in its basal portion, not the sheath for the piercing apparatus, but has only a rather shallow furrow, which in the anterior section of the beak where the trunk of the stem of the labium divides into the paired palpi, at least in Pulex, forms two flaps, laterally enclosing the puncturing organs.

"But the maxillae act vicariously (and herein lies a fundamental difference from the dipterous type), in the lack of protection by the base of the sucking tube. They arise as two broad plates on each side of the head, and protect not only the components of the puncturing apparatus, but also the base of the under lip."

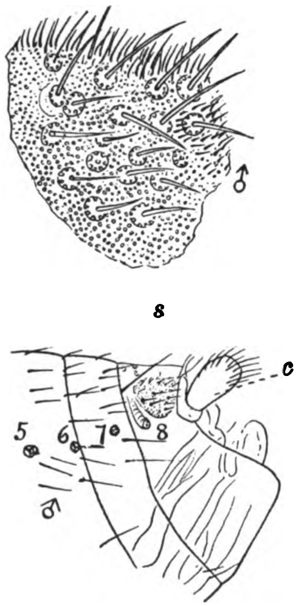


FIG. 15. End of body of *Pulex canis* ♂, with what appear to be a pair of 2-jointed cercopods (*c*); also *s*, the sensitive area (above 8), and the same more highly magnified; 5, 6, 7, 8, spiracles of the corresponding segments.

"We seek in vain for all these analogous relations in the Diptera, and the assertion is therefore correct, that all the parts of the pulicid beak—with the sole exception perhaps of the upper lip—as regards their position and use are so different from the homologous structures of Diptera that as to the direct phylogenetic relations of the two types of beak nothing can be said."

"For similar conclusions as to the relationship of the Pulicidae and Diptera we may pass to the second group of charácteristic marks; viz. those of the structure of the thorax and its dorsal appendages. Instead of the universally free and moveable head of the Diptera, we have in the Pulicidae the broad union of the same with the prosternum. Instead of the compact thorax with its scutellum so characteristic of the Pupipara, we have the three separate thoracic segments, without any trace of any dorsal mesothoracic projection. Instead of a pair of wings, and, even in the extremest cases of parasitism, reduced halteres, nothing, absolutely nothing, as to the

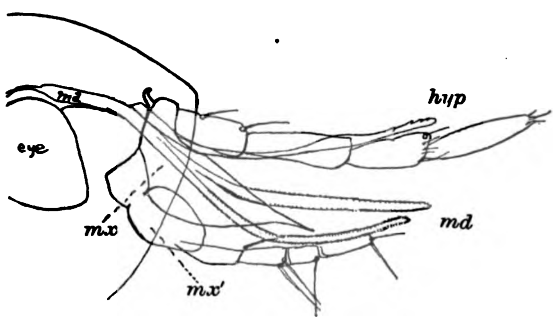


FIG. 16. Mouth-parts of *Pulex irritans*. (Specimen from Paris.)

former possession of such organs in the fleas can be predicated. Indeed, the three-fold division of the thorax referred to should have *a priori* forbidden the thought of rudimentary wings. The 'projection of the pleura' ['wing-like scales' of Wagner] have nothing to do with rudimentary wings, and are as characteristic structures, *sui generis*."

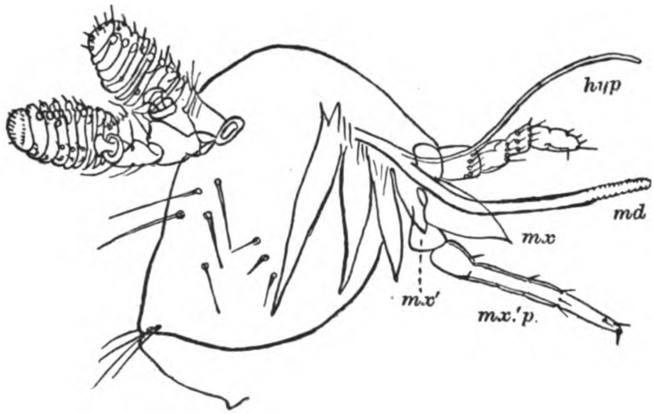


FIG. 17. Head, with antennae of the eyeless flea of the European mole. (*Typhlopsylla* sp.)—Figs. 11–17, *Author del.*

The general relation and shape of the mouth-parts of the Pulicidae are shown by Figs. 11–17. I need not enter into a prolix description of them, and will only add that in the explanation of the figures, the lettering is the same for all.

Internal organs.—Kraepelin then takes up the internal organs and compares those of the fleas with those of the flies. The "sucking stomach," which apparently will be found to exist in all groups of Diptera, is wholly wanting in the Pulicidae, while on the other hand, the proventriculus of the latter, beset on the inside with toothless, chitinous spines (Fig. 18, *B*), should remove any analogy to the Diptera. The mechanism for sucking of the pharynx, or of the so-called fulcrum of the Diptera, is formed by a single powerful pair of muscles ; in the fleas on the other hand, as well as in the Rhynchota, there is a whole series of separate pairs of muscles for this function, which were regarded by Landois as flexors and retractors of the labrum. Finally the presence of a stigma in the prothorax of the fleas points to deeper differences

in the tracheal system, while for the simple ocelli of the Pulicidae, as also for the deep lateral cavity of the head, there are analogies in the Rhynchota but not in the Diptera (Kraepelin).

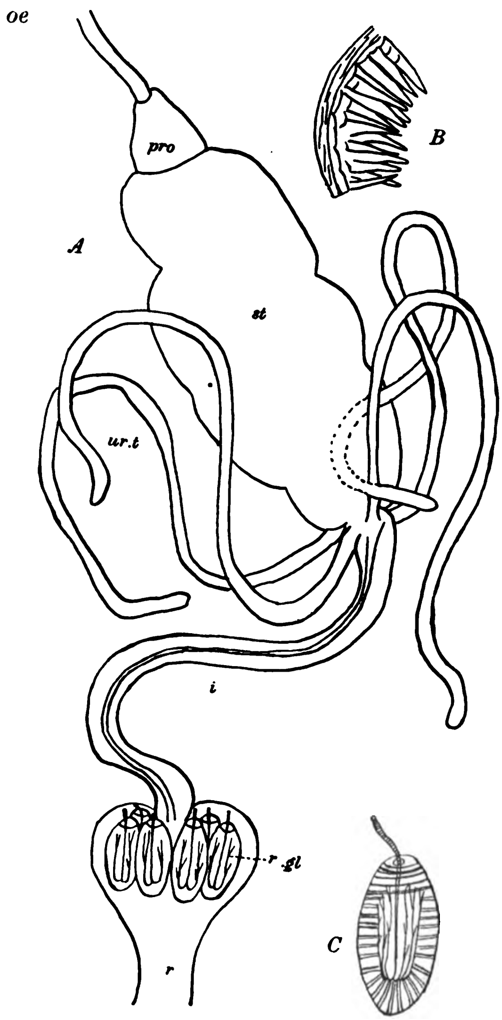


FIG. 18. *A*, alimentary canal of *Pulex canis; oe*, oesophagus; *pro*, proventriculus; *st*, stomach; *i*, intestine; *ur.t*, urinary tubes; *l.i*, large intestine; *r.gl*, rectal glands; *r*, rectum; *B*, teeth-like processes lining the proventriculus; *C*, one of the six rectal glands, showing the trachea and its branches.—*After Landois.*

Both Landois and Wagner figure the six rectal glands, which do not materially differ from those of other insects (Fig. 18, *A*, *r.gl*).

The Hypopharynx.

Opinion regarding the homology of this unpaired piercing organ is by no means settled, and while there is a general agreement as to the nature of the paired mouth-parts, recent observers differ very much as to the morphology of the organ in question.

It is the langue or *lingua*[1] of Savigny (1816), the *ligula* of Kirby and Spence (1828), the *langue ou languette* (*lancette médiane du suçoir*) of Dugès (1832), the *lingua* of Westwood (Class. ins., 2, p. 489, 1840), "the unpaired median piercing organ" ("the analogon of the epipharynx of Diptera") of Karsten (1864), the "tongue" of Taschenberg (1880).

Landois (1866) calls it the "stechorgan," not giving it a scientific Latin name in the text of his description, but adding the word *labrum* in the explanation of the plates. He correctly figures and describes it, stating that it lies between the mandibles, and within the head expands into a flask-shaped portion provided with a chitinous edge on each side. Behind this point the chitinous edges diverge from each other like a pair of legs, forming the support for retractor muscles. Directly behind the enlarged, flask-shaped portion between the chitinous legs begins the pharynx which dilates directly behind its origin, then contracts and passes into the oesophagus. The anterior portion of the pharynx forms a membranous tube provided with muscles, into which the bladder-shaped and other salivary glands open (Fig. 19).

By this description of Landois it will thus be clearly seen that this organ has nothing to do with a labrum or epipharynx, but belonging to the floor of the mouth, in close relation to the labium, and receiving the salivary duct, must be a true hypopharynx. Like Karsten, he detected the ending of the salivary duct at this point.

We copy Landois's figure of the hypopharynx as a whole (Fig. 19), and add a sketch of the hard parts observed in the flea of the European hedgehog (Fig. 23).

[1] Landois erroneously writes "ligula," p. 18. This author also misrepresents Dugès ("labrum, Dugès") who emphatically states that the labrum does not exist in Pulex (*et il y a chez le taon un labre qui n'existe pas chez la puce*), p. 151.

In *Pulex canis*, according to Landois, the hypopharynx, together with the mandibles, situated on each side of it, forms a closed sucking tube.

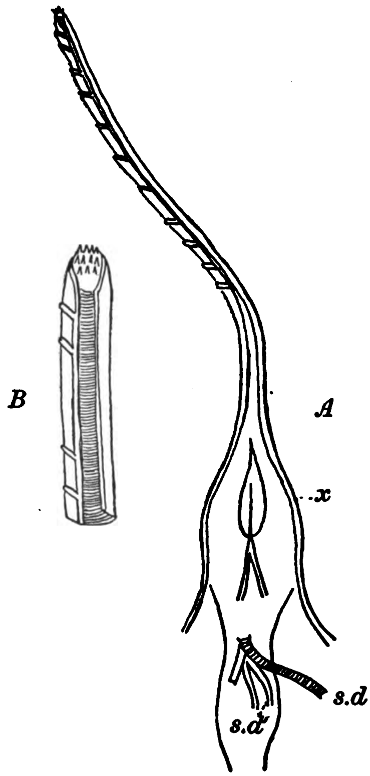


FIG. 19. *A*, hypopharynx of *Pulex canis*; *x*, basal portion situated within the head; *s.d*, common duct of the four bladder-shaped salivary glands; *s.d'*, opening of the tubular salivary glands into the throat; *B*, end of the hypopharynx, showing the gutter-like structure and teeth at the end.—*After Landois.*

As the result of his transverse sections of the flea's beak, Kraepelin was led to deny the existence of a hypopharynx in Siphonaptera. He states his belief that the hypopharynx, present in all Diptera, is in the Pulicidae entirely wanting. "This absence of the hypopharynx results in a wholly different use of the mandibles and the formation of a very peculiar type of sucking

tube, and is important in affording an outlet for the salivary gland into the mandibles. The two salivary ducts pass as a slender furrow along the inner side of each mandible, becoming at the base a closed canal and extending within the head to the salivary glands situated in the thorax."

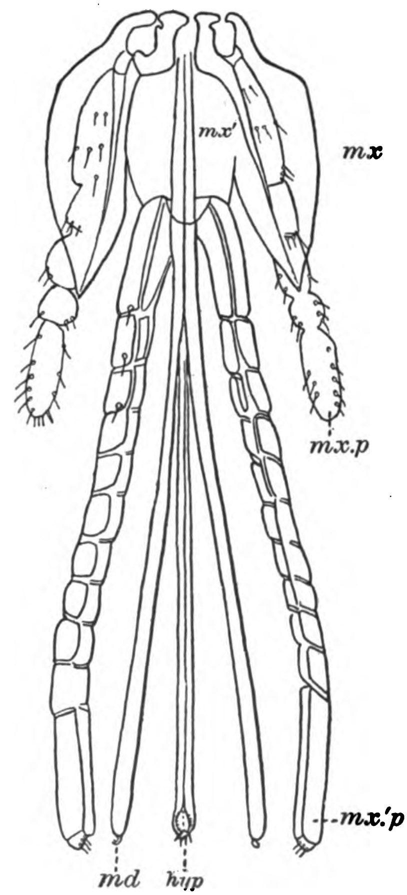


FIG. 20. Beak of Vermipsylla.—*After Wagner.*

In his account of the "unpaariges stechorgan," J. Wagner, as he states in a footnote, adopts Landois's German name for it, "since the homology of this organ is not yet settled." In *Vermipsylla alacurt* he describes it as a chitinous tube, somewhat

dilated at the distal end, whose lateral walls are at the end rolled up. In a transverse section through the base of the mouth-parts, his figure, which we copy (Fig. 21), the sides of the tube are continued down in the form of two chitinous bands turned down opposite each other. These two bands in union with the two mandibles (oberkiefern) surround the canal (Fig. 21, *a*) which he regards as the true sucking tube. "But the tube which is formed by the unpaired organ itself serves for the exit of the secretions of the salivary glands, which are seen farther below. From each side of it arise two processes like those beneath. Each is rolled up longitudinally and fits into a corresponding recess of the mandibles, thereby serving to keep the latter, with the unpaired organ, in a fixed position. At the end of the mouth-parts the lateral processes disappear. The inner side of the tube is traversed by dark cross-lines, which are only furrows. On the back of the unpaired organ, on the side opposite the sucking tube, is a high ridge (Fig. 21) which is to be seen only on the distal half of the organ. On this ridge near the end of the unpaired organ are two minute teeth, and from these passing obliquely to the base of the ridge are two transparent streaks which, according to Landois, arise from two small transparent canals."

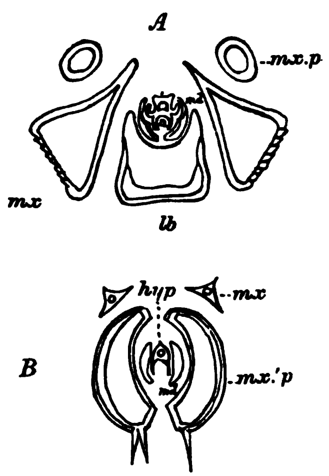


FIG. 21. Section through the beak of Vermipsylla; *A*, through the base; *B*, through the end; *s*, opening in the hypopharynx for the salivary duct.—*After Wagner*.

Similar structures occur in the unpaired organ of all known Siphonaptera (Sarcopsylla, Rhynchopsylla, Pulex); they only differ in the number and distribution of the teeth. On the inner side at the end of the organ described occur such protuberances and spinules as are found in the dog flea.

In the appendix he thus refers to Kraepelin's paper which he had not seen when writing his article: "Kraepelin considers the unpaired piercing organ of the flea as the labrum (overlippe) for

the reason that it is united with the head and pharynx in the same way as the labrum of Diptera, and because, like the labrum of Diptera, it assists in the work of sucking, since it completes the back of the sucking tube, being curved down on each side of it. Moreover the mandibles on each side contain a deep furrow in which the two outlets of the salivary glands open. I have before shown that two ducts of the salivary glands in Vermipsylla, which lie in the basal portion of the abdomen, unite near the head into a single efferent duct which first passes into the pharynx and then goes into the unpaired piercing organ. Since I do not suppose that Vermipsylla is an exception to other fleas, I think that Kraepelin has not seen this salivary duct. Moreover, without entering into the mode of attachment of the unpaired piercing organ, I see in the very fact that the common efferent duct of the salivary glands passes into the piercing organ, a decisive proof against the view that it is the labrum. Landois (p. 27) also speaks of a common duct passing out from his 'bladder-like salivary gland,' which must enter the pharynx, but which he had not traced so far. Should we bring this statement into harmony with the view of Kraepelin, then must we adopt the view that the piercing organ represents two parts: the labrum and the hypopharynx (epipharynx)?" It may be observed that Wagner entirely agrees with Kraepelin as to the nature of the labium, though he differs both from Taschenberg and from Kraepelin in regarding the fleas as "a very specialized group of Diptera."

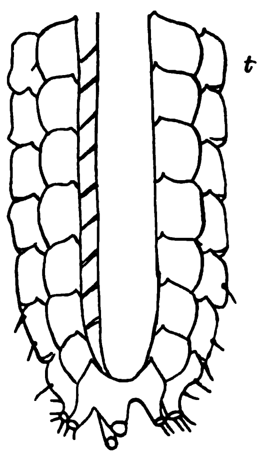


FIG. 22. End of mandible of Vermipsylla, highly magnified: *t*, teeth.—*After Wagner.*

Our own scanty observation on this organ, made mostly from examination of a slide of the flea of the European hedgehog (*Pulex erinacei* Bouché, Fig. 23), shows that it agrees with the figure of Landois (Fig. 19). At its base within the head it divides into two separate rods (*stili hypopharyngi*, *st*) which protect the end of the efferent duct. In the specimen drawn, the base of the

hypopharynx appears to lie above the base of the mandibles, but below that of the maxillary palpi.

The true relations of this unpaired organ undoubtedly need further elucidation, but at present I am inclined to take the view that it is the homologue of the hypopharynx of Diptera, the point deciding me being the fact that, as in Diptera, it contains the efferent duct and opening of the salivary glands which in all other insects is situated in the hypopharynx or in a homologous portion (tongue, lingua, "spinneret" of caterpillars) of the second maxillae.

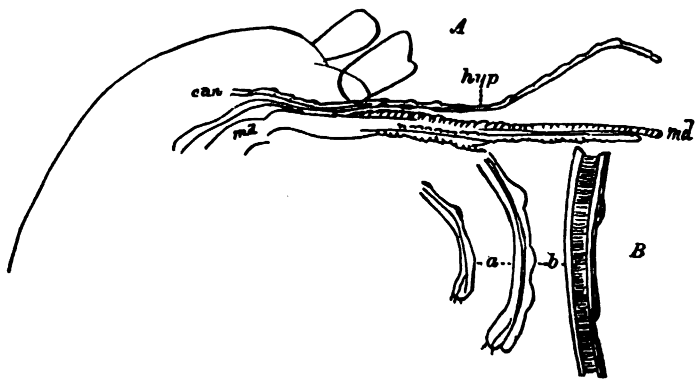


FIG. 23. *A*, portion of the mouth-parts of *Pulex erinacei; hyp*, hypopharynx; *can*, place where the salivary canal enters between the styles of the hypopharynx; *B*, *a*, *b*, end of the hypopharynx with a portion of the middle highly magnified showing its gutter-like shape.—*Author del.*

The identification of the hard parts is rendered peculiarly difficult in the Siphonaptera owing to the unusual shape of the head, which is without a labrum or epipharynx, a loss due to adaptation to its suctorial habits and semiparasitism; and to the unusual position of the base of the mandibles and maxillae, though as will be seen by the sections of Kraepelin and of Wagner the hypopharynx is embraced by the mandibles, and lies immediately over the labium, this being the normal position of the hypopharynx of other insects.

In order to bring out with exactness the true nature of the hypopharynx of Diptera and other insects, I will give a brief résumé of the knowledge of this unpaired organ, which is the

highly specialized portion of the tongue or lingua of mandibulate non-suctional insects.

The name hypopharynx was first proposed by Savigny[1] in 1816, who, after naming the membranous plate which has for its base the upper side of the pharynx, the *epipharynx*, remarks: "Dans quelques genres, notamment dans les Eucères, le bord inférieur de ce même pharynx donne naissance à un autre appendice plus solide que le précédent, et qui s'emboîte avec lui. Je donnerai à ce dernier le nom de *langue* ou d'*hypopharynx*. Voilà donc la bouche des Hyménoptères composée de quatre organes impaires, sans y comprendre la ganache ou le menton; savoir, la lèvre supérieure, l'épipharynx, l'hypopharynx, et la lèvre inférieure, et de deux organes paires, les mandibules et les mâchoires."

By far the most complete anatomical and physiological account of the hypopharynx of Hymenoptera is that of the worker honey bee by Cheshire in his valuable "Bees and Bee Keeping," 1886.[2] He calls it the tongue or ligula. It is situated in a tube formed by the maxillae and labial palpi, and can be partially retracted into the mentum. He states that it can move up and down in the tube thus formed, and then describes it as covered by a hairy sheath, its great elasticity being due to a rod running through its center enabling it to be used as a lapping tongue. The sheath

"passes round the tongue to the back, where its edges do not meet, but are continuous with a very thin plaited membrane (*p m*) covered with minute hairs. This membrane, after passing towards the sides of the tongue, returns to the angle of the nucleus, or rod, over the under surface of which it is probably continued. The rod passes through the tongue from end to end, gradually tapering towards its extremity, and is best studied in the queen, where I trace many nerve-threads and cells. It is undoubtedly endowed with voluntary movement, and must be partly muscular, although I have failed completely in getting any evidence of striation. The rod on the under side has a gutter, or trough-like hollow (*c d*, the central duct) which is formed into a pseudotube (false tube) by intercrossing of black hairs. It will also be seen that, by the posterior meeting of the sheath, the space between the folded membrane (*s d*) becomes two pseudotubes of larger size, which I shall call the side ducts."

[1] Mémoires sur les animaux sans vertèbres. Part. I. Mém. 1–2. Théorie des organes de la bouche des crustacés et des insectes. Paris, 1816, p. 12, 13.

[2] See also, Breithaupt, Ueber die anatomie und die functionen der bienenzunge, 1886, which I had not seen until this article was in type. It confirms and extends Cheshire's work.

"These central and side ducts run down to that part of the tongue where the spoon, or bouton (*b*, Plate II; *K*, Plate III), is placed. This is provided with very delicate split hairs (*E*, Fig. 25), capable of brushing up the most minute quantity of nectar, which by capillarity, is at once transferred by the gathering hairs (which are here numerous, long, and thin) to two side groove-like forms at the back of the bouton, and which are really the opened out extremity of the centre and side ducts, assuming, immediately above the bouton, the form seen in *F*, Plate III. The central duct, which is only from $\frac{1}{800}$ in. to $\frac{1}{1000}$ in. in diameter, because of its smaller size, and so greater capillary attraction, receives the nectar, if insufficient in quantity to fill the side ducts. But good honey-yielding plants would bring both centre and side ducts into requisition. The nectar is sucked up until it reaches the paraglossae (*pg*, *B*, Plate III), which are plate-like in front, but membranous extensions, like small aprons, behind; and by these the nectar reaches the front of the tongue, to be swallowed as before described."

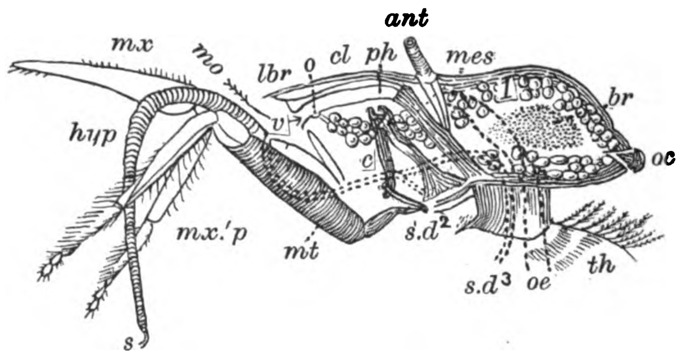


FIG. 24. Longitudinal section through the head of the honey bee ♀, just outside of right antenna; *ant*, antenna with three muscles attached to *mes*, mesocephalic pillar; *cl*, clypeus; *lbr*, labrum; 1, chyle gland (system no. 1, of Siebold); *o*, opening of the same; *oc*, ocellus; *br*, brain; *n*, neck; *th*, thorax; *oe*, oesophagus; *sd*$^{2\,3}$, common salivary ducts of systems 2 and 3; *sv*, salivary valve; *c*, cardo; *ph*, pharynx; *mx'*, labium; *mx.'p*, labial palpi; *mt*, mentum; *mx*, maxilla; *hyp*, hypopharynx; *s*, bouton.—*After Cheshire.*

Cheshire then settles the question which has been in dispute since the time of Swammerdam, whether the bee's tongue is solid or tubular. He agrees with Wolff that the duct is a trough and not a tube, and proves it by a satisfactory experiment. He remarks:

"Bees have the power, by driving blood into the tongue, of forcing the rod out from the sheath, and distending the wrinkled

membrane so that in section it appears as at H, Plate III [our fig. 25], the membrane assuming the form of a pouch, given in full length at A. It will be seen at once that this disposition of parts abolishes the side ducts, but brings the central duct to the external surface. The object of this curious capability on the part of the bee is, in my opinion, to permit of cleaning away any pollen grains, or other impediment that may collect in the side ducts. The membrane is greasy in nature, and substances or fluids can be removed from it as easily as water from polished metal. If, now, the sides of a needle, previously dipped into clove oil in which rosanilin (magenta) has been dissolved, so as to stain it strongly red, be touched on the centre of the rod, the oil immediately enters, and passes rapidly upwards and downwards, filling the trough."

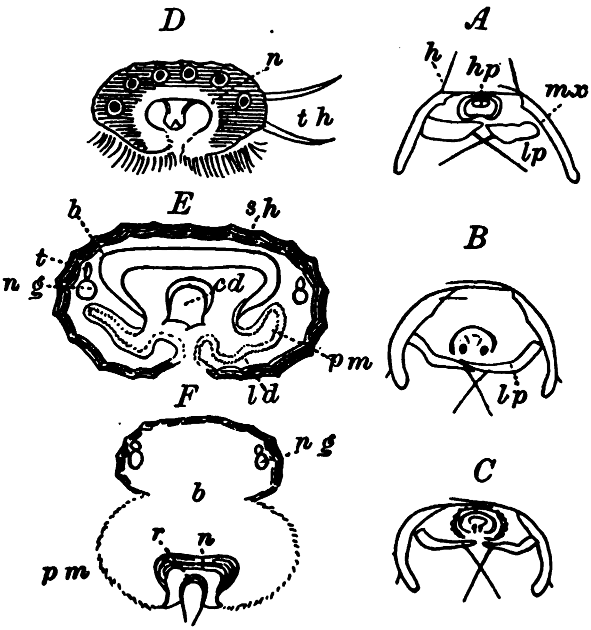


FIG. 25. *A–C*, section of bee's tongue; *D*, cross section of extremity of tongue near the "spoon"; *th*, tactile hairs; *r*, rod; *n*, nucleus; *gh*, gathering hairs; *E*, cross section of tongue without gathering hairs, × four hundred times; *sh*, sheath; *b*, blood space; *t*, trachea; *ng*, gustatory nerve; *cd*, central duct; *ld*, lateral duct; *pm*, plaited membrane; *F*, same as *E*, but magnified two hundred times, and with *pm*, plaited membrane, turned outwards; *h*, closing hairs; *lp*, labial palpi.—*After Cheshire.*

The hypopharynx of the Diptera is readily recognized, and has nearly the same high degree of development as in the honey bee, and the same relations to the other mouth-parts. It arises from the floor of the pharynx, and lies above the labium or second

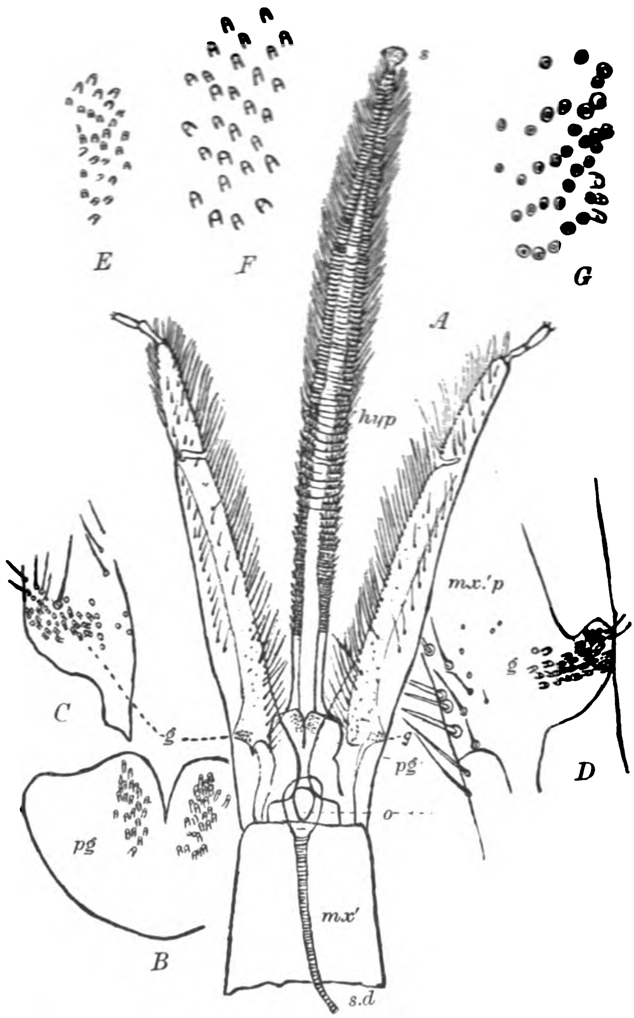


FIG. 26. *A*, tongue of worker honey bee; *pg*, paraglossae; *B*, the paraglossae enlarged; *C*, *D*, base of a labial palpus (*mx.'p*) showing the taste papillae; *E*, taste cups on paraglossae of Bombus; on left side *F*, on right side *G*, on base of labial palpus.—*Author del.*

maxillae, and these relations are also plainly seen, as will be observed in the figures which I copy from Meinert and others. It is to be observed that the term hypopharynx is almost universally given to this unpaired piercing organ of the Diptera, few writers calling it the lingua or ligula.

The best account of it up to 1881 is that of Dimmock, who says:—

"The hypopharynx is usually present in diptera (according to Menzbier absent in *Sargus*), and contains a tube, opening by a channel on its upper surface; this channel extends back, more or less, from the tip, and is the outlet for the salivary secretion. The tip of the hypopharynx may be naked and used as a lance (*Haematopota*, according to Menzbier), or may be hairy (*Musca*). The upper side of the base of the hypopharynx is continuous with the lower wall of the pharynx; its under surface may entirely coalesce with the labium (*Culex*, male), may join the labium more or less, anterior to the mouth (*Musca*), or, if either mandibles or maxillae are present, its base may join them (*Culex*, female)' (p. 43).

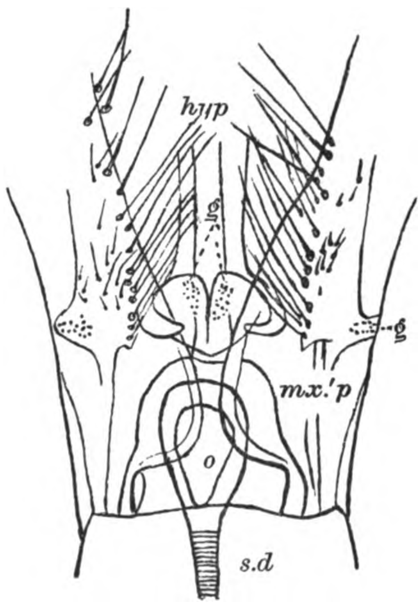


FIG. 27. A portion of the same as Fig. 26, *A*, enlarged; *o*, opening of the salivary duct (*sd*).—*Author del.*[1]

Meinert, in his detailed and elaborately illustrated work, "*Trophi Dipterorum*" (1881), has made an advance on our knowledge of the hypopharynx and its homologies, both by his evidently faithful descriptions and dissections, and by his admirably clear figures, some of the most important of which I repro-

[1] Figs. 26 and 27 are drawn from a slide of a bee's tongue kindly loaned me by Mr. N. N. Mason, which shows well the salivary duct and tongue, and the gustatory organs near the base of the latter on the paraglossae.

duce. In the Latin theses or résumé of his work, which is written in Danish, he thus describes this organ and the salivary duct, which we translate:—

"The hypopharynx, a continuation of the lower edge (*lamina*) of the pharynx, most generally free, more or less produced, acute anteriorly, forms with the labrum the tube of the pump (*antliae*). (The hypopharynx when obsolete, or coalesced with the canal of the proboscis is the theca; in such a case the siphon or tube is formed by the theca and labrum.) Meanwhile the hypopharynx, the largest of all the trophi (*omnium trophorum maximus*), constitutes the chief piercing organ (*telum*) of Diptera. The hypopharynx is moved by protractor, most generally quite or very powerful, and by retractor muscles."

"The efferent duct of the thoracic salivary glands—*ductus salivalis*—perforates the hypopharynx, more or less near the base, that the saliva may be ejected through the canal into the wound, or that it may be conducted along the labella. Very rarely the salivary duct, perforating the hypopharynx, is continued in the shape of a free, very slender tube."

"The salivary duct behind the base of the hypopharynx forms the receptacle or *receptaculum*, provided with retractor and levator muscles."

These parts are clearly shown in the accompanying figures copied from Meinert, and which need little explanation.[1]

In his elaborate and beautifully illustrated work entitled "Fabrica oris Dipterorum," 1883, H. J. Hansen describes and figures the mouth-parts of species of the families Tabanidae, Asilidae, Therevidae, Mydaidae, and Apiocerinae. He also

[1] Meinert also describes the *ligula* or tongue, which, he says, "is concealed between the labella, and is often wanting, sometimes provided with paraglossae." Here it might be said that Meinert maintains that the first metamere of the head is divided into a ventral and a dorsal part. The ventral part is the *proboscis*, the labium of other authors. His dorsal part (of the first metamere) united with the epipharynx forms the labrum. His "second metamere" forms the entire ring of the head, and its ventral part bears the maxillae of other authors, which Meinert calls *scalpellae*. The pleurae of the "second metamere" bear the mandibles of other authors, the *cultelli* of Meinert. The palpi usually are appended to the ventral, rarely to the dorsal portion of the second metamere. He then adds: "Behind the second metamere, the third metamere of the head, often a very small unarmed ring, is coalesced with the *lamina cephalica*."

It is to be observed that in this otherwise very valuable and carefully prepared memoir the author does not seem to attempt to homologize the mandibles and maxillae and the palpi, with those of other insects, nor does he appear to be guided by our present knowledge of the embryological development of the insect head; and it seems to me that he fails to make use of modern morphological methods in dealing with the more general aspects of the subject of the homologies of the insect segments and their appendages.

gives good figures illustrating the relations of the salivary duct and the hypopharynx to the other parts of the mouth. He does not employ Meinert's terms for the mandibles, maxillae, and maxillary palpi, though his figures confirm the accuracy of Meinert's anatomical work.

The excellent essay of Müggenburg on the beak of *Diptera Pupipara* gives large, clear figures of the hypopharynx, and confirms the general accuracy of Meinert's observations. I copy

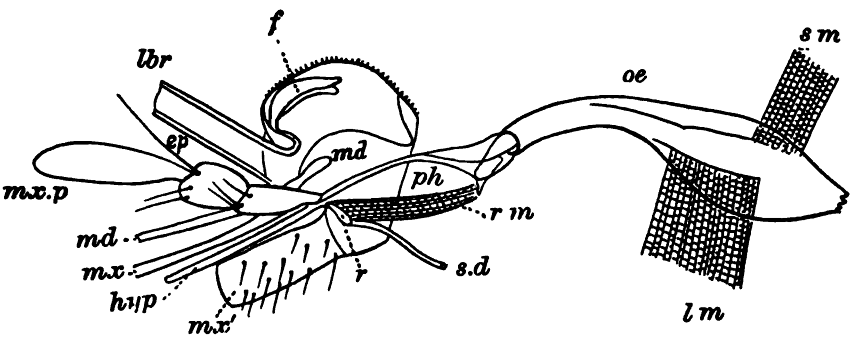


FIG. 28. *Culex pipiens*, section of head; *oe*, oesophagus; *sm*, upper muscle, *lm*, lower muscle of the oesophagus; *ph*, pharynx; *rm*, retractor muscle of the receptacle (*r*) of the salivary duct (*sd*); *lbr*, labrum; *ep*, left style of the epipharynx; *f*, part of front of head.—*After Meinert.*

them, without a lengthy explanation. In Hippobosca the very peculiar beak is composed of the labrum, hypopharynx, and labium. I translate the following:—

"The dorsally situated channel of the labrum together with the ventral furrow of the upper surface of the hypopharynx form the alimentary canal; the salivary fluid is conducted out into the inner cavity of the hypopharynx; finally the labium encloses these parts of the beak like a protecting case, and so completely that only on a superficial view could we regard it as a beak" (p. 8).

"*The hypopharynx.* The middle one of the three bristles (Fig. 34, *hy*) is a very thin, long, small chitinous band, clear as glass, through the middle of which passes an extraordinarily fine canal, circular in cross-section, whose course may be externally recognized by a corresponding fullness of the chitine. The bristle takes its origin from the upper plate of the third stilet, the labium, with which it is firmly united for a short distance at the base, a relation which is generally characteristic of the hypopharynx of Diptera (Fig. 35, *hy*)."

"I should also add that the fact, that the efferent passage of the thoracic salivary glands is continued as the canal of the seta in question is an additional sure proof of its interpretation as the hypopharynx (Fig. 23, *hy*). I have earlier urged that this generally agrees with the structure of the armature of the mouth-cavity. It only varies in the form and size of the parts of which it is composed. In the special case before us the ribbon-like hypopharynx lies flat on the incurved edges of the labrum, and thus bridges over the ventral longitudinal opening of the food-passage (Fig. 8, *hy*). The swollen portion of the dorsal wall of the salivary duct serves as a support between the labrum and hypopharynx, while like the groove in a rabbet it fits tightly into the opening of the tube, and thus prevents a lateral displacement of both of the mouth-parts. But the end of the hypopharynx in which the external end of the salivary duct opens, projects anteriorly in the opening of the mouth as a small free piece beyond the shorter labrum."

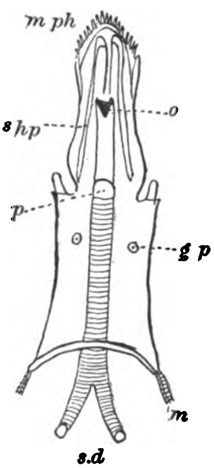


FIG. 29. Pharynx and hypopharynx of *Simulium fuscipes*; *lph*, lower lamina of the pharynx; *p*, the salivary duct (*sd*) perforating the pharynx; *o*, orifice of the duct; *shp*, styles of the hypopharynx; *mph*, membranous edge of the hypopharynx; *m*, protractor muscle of the pharynx; *gp*, gustatory papillae? — *After Meinert*.

Müggenberg then briefly describes the mouth-parts of *Braula coeca*, adding excellent and clear figures, two of which we copy. He states that the mouth-parts are very different from those of other Pupipara. There is a large lunate clypeus. The short beak is composed of the same parts as in the Hippoboscidae, viz., the labrum, hypopharynx, and labium (Fig. 34, *lbr*, *hp*, *lb*). The labium ends in two hairy leaves, the homologues of the labella of the Muscidae. The maxillary palpi (Fig. 33, *mxp*) are short, strongly setose lobes which project from each side of the clypeus. These rudimentary maxillary palpi take no part in the act of sucking.

Finally, having in detail reviewed the literature descriptive of

the parts of the dipterous beak[1], especially the hypopharynx, we are led to believe that the "unpaired piercing organ" of Siphonaptera is a true hypopharynx, with the same homologies, arising in

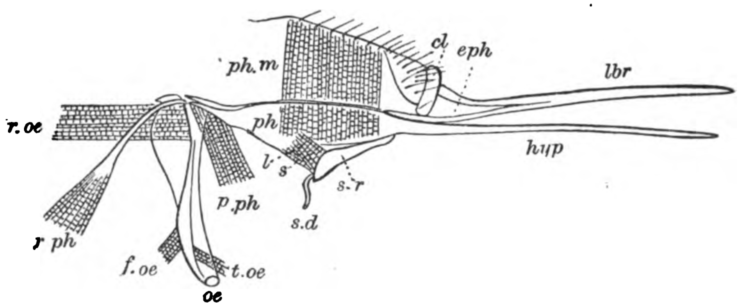


FIG. 30. Labrum-epipharynx (*lbr* and *eph*) and hypopharynx (*hyp*) of *Tabanus brominus*; *oe*, posterior cylindrical portion of the oesophagus; *aoe*. anterior swollen portion of the same; *ph*, pharynx; *ph.m*, pharyngeal muscle; *p.ph*, protractor muscle of the pharynx; *roe*, retractor muscle of the oesophagus; *rph*, retractor muscle of the pharynx; *f.oe*, flexor muscle of the pharynx; *t.oe*, twisting muscle of the oesophagus; *sr*, receptacle of the salivary duct; *l*, its elevator muscle; *s*, its retractor muscle; *cl*, clypeus. —*After Meinert.*

the same manner from the lower edge of the mouth and having morphologically no connection with the upper edge of the mouth, though as the result of adaptation and modification it does seem to arise from just under where the labrum is in Diptera. The strongest point, moreover, in favor of the view that it is a true

[1] I am unable to agree with Prof. J. B. Smith's views of the homologies of the mouth-parts of Diptera. (Trans. Amer. ent. soc., v. 17, p. 319, Nov. 1890.) He has kindly allowed me to see his preparations of the mouth-parts of Simulium. I was led to doubt his conclusions from my studies on the hypopharynx of the fleas, and from an examination of the works of Meinert, Hansen, and Müggenberg, which he had apparently not seen. What he figures and regards as the "mandibles" of certain species of Simulium appear to be the homologues of the teeth at the end of the hypopharynx of other species of Simulium, *i. e.*, the New England one, and that figured by Meinert (my Fig. 29). I also see no reason for Smith's regarding the proboscis, with the labella, as parts of the first maxillae. His "galea" is the labella of all authors; his "palpifer" is the true maxilla; his "lacinia" I regard as the mandible, this also being the view of Meinert (though Meinert calls it the "cultellus"), Hansen, and previous authors. It would be singular if the two sets of teeth at the end of the hypopharynx were really homologues of the mandibles, because they are simply an armature situated at the end of the hypopharynx, and that this portion is that organ is proved by the fact that the salivary duct opens into it, and that it forms the floor of the mouth.

hypopharynx is the fact that it encloses the end of the salivary duct. This shows that it is an outgrowth of the 2d maxillae or labium. The type of beak of the Siphonaptera, then, seems on the whole to be more like that of the Diptera than that of any other order of sucking insects, the resemblance being seen in the presence of a hypopharynx and of a labium, while the composition of the beak differs remarkably in the absence of a labrum.

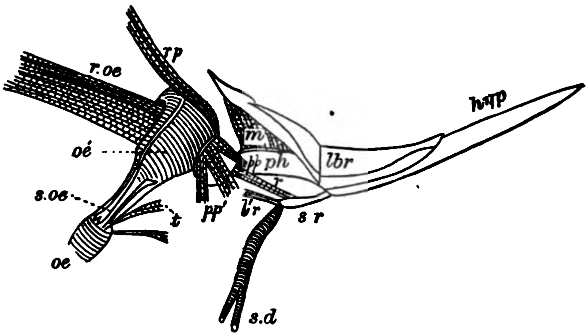


FIG. 31. Oesophagus (*oe*), pharynx (*ph*) with epipharynx (*eph*), and labrum (*lbr*) of *Asilus atricapillus; mph*, pharyngeal muscle; *sr*, salivary receptacle; other lettering as in Fig. 30.—*After Meinert.*

Hence I am unable to agree with Kraepelin that the piercing organ is the labrum, and I coincide with the view of Wagner that it cannot be that part.

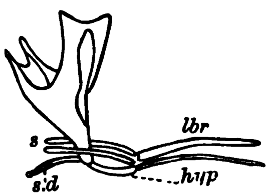


FIG. 32. Hypopharynx of *Stomoxys stimulans; p*, posterior, *a*, anterior part of the hypopharynx; *s*, styles of the labrum.—*After Meinert.*

The Siphonaptera, then, differ from the Diptera, as respects the beak and its accessories, in the lack of a clypeus or hypostoma, and of a labrum, while the mandibles are large and well developed, adapted only for piercing the flesh, being serrate on each side. The maxillae also are well developed, consisting of an acute, broad, blade-like piercing lobe, with a 5-jointed palpus stretched out like an antenna, while the labium is represented by a minute basal portion apparently giving origin to the hypo-

pharynx, and to the pair of large 5-jointed (or 11–13-jointed in Vermipsylla) labial palpi. If this view should be proved to be correct, it will tend to show that the Siphonaptera are an order parallel and near to the Diptera, but not directly derived from them, though both may have had a common origin.

Other Characteristics of the Siphonaptera.

Absence of a clypeus and labrum.—The fleas differ from any Diptera, even including the suctorial Pupipara and Braula, in the absence of a clypeus and labrum, while the antennae are inserted either above or behind the simple eyes. The head is greatly

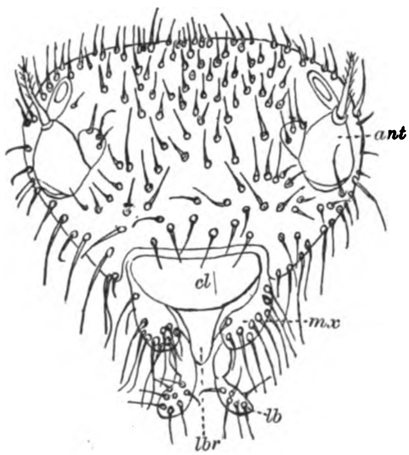


Fig. 33. Head of *Braula coeca; cl*, clypeus; *lbr*, labrum; *mx*, maxilla; *mx'*, labium; *lb*, labellum; *ant*, antenna.—*After Müggenberg.*

developed in front of the eyes and antennae in adaptation to their semiparasitic mode of life and to their peculiar mode of running through the forest-like mass of hair of their host, and of taking their food. The base of the mouth-parts, being adapted exclusively for piercing the tissues of their host and sucking blood, are, as in the suctorial Hemiptera, inserted or retracted far within the head, and there is no need of a clypeus and labrum to brace the front part of the head. This absence of a clypeus or hypostoma, as well as the absence of vestigial wings and of sternites, suggests

the view that the Siphonaptera are not a direct offshoot of the dipterous order.

The stigmata.—Although Wagner maintains that there are three pairs of thoracic stigmata, I do not find more than two pairs of thoracic and eight pairs of abdominal stigmata. Each prothoracic spiracle is situated on the lower and hinder edge of the prothoracic tergite near the base of and behind the epimerum. The mesothoracic stigmata are easier to detect, and are situated on the hinder edge of the mesothoracic segment at the base of the epimerum. What Wagner designates as the metathoracic stigmata I regard as the first abdominal pair. Wagner states that they differ in structure from those in front, remarking: "The stigma of the wing-like scale is constructed entirely as in the abdominal stigmata."

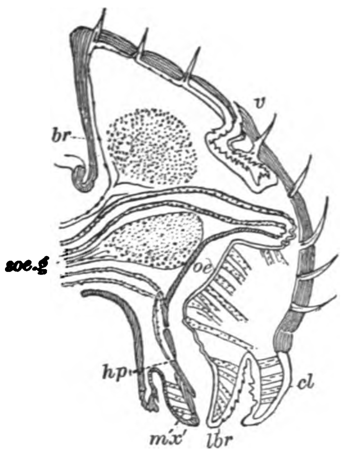


FIG. 34. Longitudinal section through the head of *Braula coeca*; *cl*, clypeus; *lbr*, labrum; *hp*, hypopharynx; *sd*, salivary duct; *oe*, oesophagus; *v*, vesicle; *br*, brain; *soe.g*, suboesophageal ganglion.—*After Müggenberg.*

On general principles we should adopt the view that there can be but two pairs of thoracic stigmata, as no existing insects are known to have a pair in each thoracic segment.[1]

The structure of the thorax.—A characteristic almost diagnostic of the fleas is the unusual equality in development of the segments, *i.e.*, their homonomy,

[1] Among dipterous larvae those of Bibio and Dilophus have ten pairs of spiracles but as Osten Sacken says, "this is a very extraordinary number, almost unique among insects. Nine pairs is the maximum number of spiracles for all the other peripneustic larvae of Diptera, and the occurrence of a supernumerary pair on the thoracic segments is a very exceptional character." He adds a parallel case referred to by Erichson of two larvae of Lampyridae from Java recorded in Westwood's Introduction, v. 1, p. 254, fig. 1, and p. 259, fig. 1, in which there is, besides the normal mesothoracic pair, a supernumerary one in the corresponding place of the metathoracic segment. "If this latter pair should prove to be spiracles then these larvae would offer a remarkable anomaly in having ten pairs of spiracles." Berlin. ent. zeitschr., 1892, p. 450.

in contrast with the subspherical shape and heteronomy of the same parts in the pupiparous Diptera, although the third thoracic segment is considerably larger than the second. Wagner also calls attention to the absence of the thoracic sternites, those of the meso- and metathorax being transformed into the entothorax, a peculiarity in which Siphonaptera differ from other insects. On the other hand, the prothoracic sternite is entirely atrophied, and there is a great development of the propleura. There appear to be no episternites. Also the insects of this order are remarkable for their free epimera, and the very large coxae.

The great development of the legs is of course an adaptive character, and this affects the great development of the pleura,

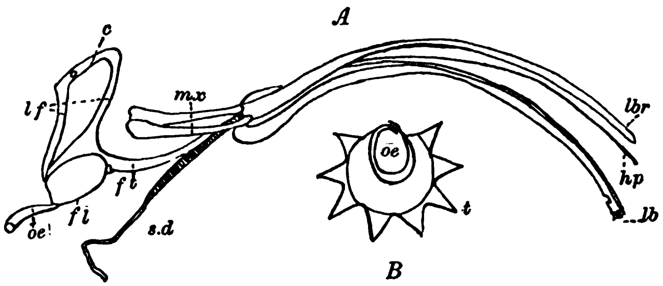


FIG. 35. Mouth-parts of *Melophagus ovinus; A, hp*, hypopharynx; *lbr*, labrum; *mx'*, labium; *lb*, labella; *sd*, salivary duct; *mx*, maxilla; *ft*, fulcrum tube; *fl*, lower fulcrum plate; *lf*, lateral continuation of the lower fulcrum plate; *B*, *oe*, oesophagus; *t*, teeth.—*After Müggenberg.*

and atrophy of the sternites, the latter being most developed in winged and cursorial insects. "While," says Wagner, "in most springing insects the femora are most developed, in the fleas the coxae are as large or larger than the femora." "In the former case we see that those muscles which are to play the chief part in springing are situated in the femora, where they are attached to the walls of the femora, and from there are continued as tendon-like structures into the tibiae. While also in this way in other insects at the instant of springing the femoro-tibial joint is extended, in the fleas the coxa is drawn back from the thorax, and it extends the femoro-coxal joint. This difference explains the flea's power of leaping, for no other insect can relatively to its size leap so high. That general mechanical law, according to

which we need for the performance of a certain movement a point of support or leverage, the greater the latter the greater being the power, acts in this case. The muscles which pass into the coxae of the hind legs are in the flea attached to the entire inner surface of the notum and the wing-like scales of the metathorax, — a fact which gives the fleas in springing such a preeminence over other insects. On the other hand, the same cause has brought about the great development of the pleurae (wing-like scales) and of the anterior diaphragm of the metathorax, since these serve as the chief points of attachment of the springing muscles. Finally the coxae in their unusual development, due to the same cause, occupy almost the entire under surface of the meso- and metathorax, and thus have produced an atrophy of the corresponding sternites, or their removal within the thorax."

Wagner sums up the other results of his observations, especially in Vermipsylla, at the end of his essay, some of which I quote :—

"The endocranium is represented by two outgrowths of which that near the eyes projects from the walls of the head, bends back towards the thorax, and reaches the hinder side of the head, with which it unites."

"The opening of the mouth is bordered above by the maxillae, beneath by the labium."

"The maxillae of fleas form a three-sided pyramid in which the muscles pass through an opening at their base."

"The pharynx serves as a sucking organ which is moved by the muscles which pass from its walls upwards to the top of the head and downward to the inner skeleton of the head."

"The abdomen of fleas consists of nine complete segments. The sternite of the first segment is united with the wing-like scales."

"The eighth abdominal segment of the male consists of a ventral and a dorsal plate. The eighth abdominal segment of the female is formed of two dorsal and two ventral pieces; in Vermipsylla the dorsal and ventral half-pieces of corresponding sides are consolidated with each other.

"The last, ninth, abdominal segment, becomes in both sexes of Vermipsylla formed by a dorsal and ventral plate.

"The anus of fleas is separate from the sexual opening at the end of the ninth segment, between the ventral and dorsal plates.

"The sexual opening, bounded on the side and beneath by the eighth sternite (in the male by the forceps of the clasping apparatus) and above by the ninth sternite, consequently lies on the ventral side of the abdomen.

"The clasping apparatus of Vermipsylla ♂ is formed by a pair of forceps which closely resemble those of a crab."

"The chitinous portion of the penis consists in general of two canals lying within each other, the inner one of which is formed of two channels, the upper and the lower. The lower channel forms with its end the point of the penis. The walls of the efferent canal of the penis are supported by two chitinous bands."

"From the vagina of Vermipsylla ♀ pass laterally two outgrowths which are attached to a special knob-like thickening of the eighth dorsal and ventral plates of the abdomen. Their function is unknown."

To recapitulate the characters in which the Siphonaptera differ from the Diptera, and which seem to prevent our including them in one and the same order, we have in the adults many characters not wholly adaptational, viz., the absence of a clypeus and labrum, of compound eyes, the head widening behind and articulated by its broad base with the prothorax, not being capable of easily turning around as in Diptera; the large hypopharynx forming a functional piercing organ; a pair of large well-developed labial palpi, while the large, long, doubly serrated mandibles are also adapted for piercing; the free homonomous thoracic segments, without vestiges of wings; the absence of sternites, the free large epimera and coxae, and the ten pairs of stigmata.

As regards the internal structure, fleas differ from flies in having no "sucking stomach," and the proventriculus is lined within with a layer of long, slender, tooth-like projections.

The footless eruciform or maggot-like larva has a more perfectly formed head than that of any known dipterous larva; an egg-shell burster is present; the brain is contained in the head; there are no coecal appendages of the stomach.

The pupa is without any vestiges of wings or halteres.

Hints as to the phylogeny of the Siphonaptera.—As to the origin of the Diptera we are at present almost wholly in the dark. This seems due to the fact that they have so widely diverged, owing to the high degree of specialization of certain organs, and the atrophy of others, from the primitive forms of the order. It is not so with the other orders of the higher metabolic insects. The Lepidoptera have apparently descended from the Trichoptera, or to state it in another way, a common ancestor may have given rise to three orders, more or less affiliated, *i. e.*, the Mecoptera (Panorpidae), the Trichoptera, and the Lepidoptera. The eruciform larva of the Tenthredinidae suggests that the Hymenoptera have descended from forms not far removed from the

ancestors of the three orders just mentioned, while we have endeavored to show that the Coleoptera may have diverged from some metabolous neuropterous form.[1]

It is not improbable that the original form of the larval Diptera was more or less eruciform, with a large head, roomy enough to contain the brain and infraoesophageal ganglion, with a definite clypeus and labrum, as well as a mental region, and with mouth-parts much more generalized and equally developed than in any existing form. The adult must have had a less highly concentrated thorax than in any existing form, the metathorax being more completely developed, and bearing a pair of wings[2]; perhaps, as in the Hymenoptera, smaller than the anterior pair. The abdomen was probably not less elongated than in the existing Tipulidae, this family, with the Bibionidae, Cecidomyidae, Mycetophilidae, etc., perhaps being the most primitive and generalized of existing Diptera.

The larva of the Siphonaptera apparently presents the nearest approach of any of the insects now existing to the shape of the primitive Diptera. It is certainly a more perfectly developed larva as regards its external structure and also the position of the brain than any dipterous one, and approaches nearer to our conception of the primitive, ancestral, dipterous larva than any other form.

Thus far no traces of temporary abdominal legs have been observed in the embryos of either the Siphonaptera or Diptera, and as I have before remarked: "The lack of these structures in dipterous embryos appears to confirm the view that they are the most extremely modified of all insects."[3]

As regards the phylogeny of the Siphonaptera we can only say, with our present imperfect knowledge of their embryology, that they seem to stand nearer to the Diptera than to any other order, and that they must have diverged from the ancestral

1 Third report U. S. entomological commission, p. 299, 1883. Also Amer. nat., 1883.

2 Rudiments of the second pair of wings are said to exist in the pupae of some of the more generalized Diptera, and the general resemblance between the pupa of Diptera and of the Tineina suggests a certain relationship between the moths and the flies.

3 A study of the transformations and anatomy of *Lagoa crispata*. Proc. Amer. philos. soc., v. 32, p. 286, 1894.

dipterous stem before the existing forms of Diptera had become so extremely specialized as we now find them to be.

The points which now need working out are the following: (1) the embryology, with reference to the presence of temporary abdominal legs; the development of the labium, and the presence or absence of the imaginal discs of the wings; (2) the presence or absence of rudiments of wings in the pupa.

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NOTE ON AGARICUS AMYGDALINUS M. A. CURTIS.

BY W. G. FARLOW.

The general opinion among mycologists is that the characteristics of the common mushroom are so marked that there is never any difficulty in distinguishing the species. This opinion is in general correct, but, nevertheless, forms are occasionally met with which vary from the ordinary described type of *Agaricus campestris*, and one is not altogether certain whether such forms are varieties of the typical form, or should rather be regarded as distinct species. The question is of interest not so much from an economic point of view — for such forms are all probably edible — as from the more scientific point of view of what should be regarded as specific marks in fungi of this kind. In this connection a few words should be said with regard to a form of mushroom which has lately attracted some attention.

I recently received from Col. Wright Rives of Washington, D. C., a quantity of fungi resembling somewhat the ordinary *Ag. campestris* and somewhat the horse mushroom, *Ag. arvensis*, a species characterized by having a double ring. The fungi made their appearance in large quantities in a greenhouse used for forcing cucumbers. Colonel Rives noted an odor and taste of almonds not found in the common mushroom. The fungi seemed to me to be the same as those described by Peck under the name of *Agaricus subrufescens* in his report as State Botanist (46th ann. rept. regents N. Y. state mus., 1893, p. 105. Separate: p. 25), from specimens received from Mr. Wm. Falconer of Glen Cove, L. I. An extended notice of the fungi was given by Mr. Falconer in the American florist of Feb. 22, 1894. Not to mention less striking characteristics, *Ag. subrufescens* is especially distinguished by its ring, which is not simply a membrane as in *Ag. campestris* nor a double membrane as in *Ag. arvensis*, but rather a thick membrane, smooth above and marked below by distinct floccose scales. If we can conceive a complete and permanent consolidation of the two membranes found in the ring of *Ag. arvensis* we should have a ring much like that actually found in *Ag. subrufescens*.

It is not necessary in this place to compare in detail the relations of *Ag. subrufescens* to varieties of *Ag. campestris* found in

Europe, but I would call attention to the occurrence in this country of certain edible fungi having a taste of almonds. In the first place, it should be said that I was unable to distinguish the odor of almonds in the fungi received from Colonel Rives, but it is a well-known fact that the odors of fungi are short-lived. The almond taste was well marked and very agreeable, and when cooked the fungi seemed to me more delicate and palatable than the ordinary cultivated form of *Ag. campestris.* The almond taste naturally suggested that the fungi in question were of the species to which the late M. A. Curtis, an authority on the subject, gave the name of *Ag. amygdalinus.* An account of the edible properties of this fungus was given by Curtis in the Journal royal horticultural society, 1870, and reprinted in W. Robinson's Mushroom culture, p. 147. It is there stated that *Ag. amygdalinus* is a new species closely allied to *Ag. arvensis*, and that the taste of almonds is lost on cooking, as was the case also in the specimens sent from Washington. The name *Ag. amygdalinus* first occurs in Curtis's list of the fungi in the Geological and natural history survey of North Carolina, p. 90, 1867, and is later given by Cooke and Berkeley in Fungi, their nature and uses, p. 88, 1875, and by Ravenel in South Carolina, resources and population, institutions and industries, p. 355, 1883. In none of the citations given is there a technical description of *Ag. amygdalinus* and we can only say that the species designated by Curtis under that name is closely related to *Ag. arvensis* and characterized by its peculiar taste. If I am correct in believing that no description of *Ag. amygdalinus* has appeared in print, the name cannot be accepted by botanists. In this connection it is of interest to know that in Curtis's copy of Ravenel's Fungi Caroliniani Exsiccati, Vol. III, No. 3, is a specimen which according to the label is *Ag. fabaceus* Berk. There is a note in Curtis's handwriting stating that this number is *Ag. amygdalinus* Curtis. Furthermore, in the Curtis herbarium there are five specimens marked *Ag. amygdalinus*, viz., "1243, in arvis arenosis, June, Society Hill; 1236, in hortis et sylvis, May, 1849, Society Hill, 1045, Rich soil in gardens, Nov. Santee Canal, Ravenel; 886, Sprague, Mass."; also two unnumbered specimens collected in Aug. and Sept., 1849. In the case of the first named specimen the name was originally written *Ag. arvensis* and afterwards corrected to *Ag. amygdalinus.* In the other cases, the name first written was *Ag. fabaceus* changed later to *Ag. amygdalinus.*

From these facts we may infer that the fungus called *Ag. amygdalinus*, while in Curtis's opinion closely related to *Ag. arvensis*, corresponded closely to the description of *Ag. fabaceus* Berk., first collected by Lea in Ohio and described by Berkeley in Hooker's London journal of botany, v. 6, p. 314, 1847, the description being repeated in T. G. Lea's "Catalogue of plants . . . collected in the vicinity of Cincinnati," p. 53, and several other places. The white, externally floccose veil is clearly described, and the fungus is said when young to have a peculiar but not unpleasant smell. It may be that since nothing was said concerning the almond taste in the original description of *Ag. fabaceus*, Curtis was led to believe that his *amygdalinus* was a different species. In spite of the fact that nothing was said by Lea concerning the taste, it seems to us that we are warranted in believing that *Ag. amygdalinus* is in reality another name applied to the older *Ag. fabaceus* Berk. The specimens sent by Colonel Rives agree well with the description of *Ag. fabaceus* and in taste and smell with what is recorded of *Ag. amygdalinus*. The description of *Ag. subrufescens* Peck., although fuller than that of *Ag. fabaceus*, does not seem to me to differ in any essential respect, and it seems to me that the fungi collected both by Mr. Falconer and Colonel Rives should be referred to *Ag. fabaceus* as the original of our North American species. Whether our species is to be regarded as identical with some older European form is a point which need not be discussed here. It is, at least, interesting that a fungus recorded by Curtis as common in the Southern States and by Morgan as common in Ohio, but which was practically unknown in the Eastern States except for the single reference by Sprague in vol. 6, p. 316, of the Proceedings of this Society, should appear suddenly in immense quantities on Long Island and in Washington. It appears to me to be one of the best of all edible fungi, but I am informed that it is regarded by dealers with suspicion in spite of undoubted testimony to its harmlessness.

General Meeting, May 16, 1894.

President W. H. Niles in the chair. Sixty-one persons present.

The following papers were read:—

THE PREGLACIAL CHANNEL OF THE GENESEE RIVER.

BY AMADEUS W. GRABAU.

Physical Features of the Region.

The Genesee River takes its rise in the highlands of northern Pennsylvania, and, entering the state of New York in Allegany County, continues to flow in a northwesterly direction for about thirty miles. Near the village of Caneadea it alters its course to east of north, which general direction it maintains until it enters Lake Ontario, nine miles north of Rochester. The river thus traverses the entire state from south to north, dividing it into two unequal portions. It also forms a natural boundary-line between the "Finger Lake" region in central New York and the almost lakeless western district.

Analysis of the modern channel.—The present channel of the Genesee admits of a division into four portions. Beginning at the south, we find a well-defined, broad, and usually flat-bottomed valley, with sloping sides which are drift covered, and, as a rule, heavily wooded. This is, in fact, a mature, preglacial river valley, cut out of the Chemung and Portage shales and sandstones which are only exposed in the lateral ravines, or cuttings. Through this valley the river pursues a meandering course, with banks composed of sand and clay, over which it annually rises, flooding the adjacent "flats." The depth at which rock would be found has not been ascertained; but, as will appear later, the valley seems to have been filled up to a considerable extent. The bottom of the valley at Portageville has an elevation of 1,050 feet A. T., and is composed mainly of alluvial material. While, however, the general nature of the valley bottom is flat, we find occasionally kame-like hills of sand and gravel, of the sugar-loaf type common in that region, and an occasional accumulation of till.

Opposite the village of Portageville, the valley appears to come to an end, the river entering upon the second portion of its channel, a rocky gorge over twenty-five miles in length, extending from Portageville to Mt. Morris. This gorge varies in width

from six hundred to about eight hundred feet, and its sides are mostly perpendicular, rising in places to a height of four hundred feet or more. In this gorge are situated the three celebrated Portage Falls, at a distance from the head of the gorge of one fourth, three fourths, and two and one fourth miles respectively, the first having a height of sixty-six feet, the second of one hundred and ten feet, and the third of ninety-six feet. The greater portion of the gorge is cut into the Portage sandstone and shales, only the lower portion, near Mt. Morris, being cut into the Genesee slate.

The third portion of the channel extends from Mt. Morris to Rochester, and is another preglacial valley in all respects similar to the one south of Portageville, except that it is wider and has its sides less distinctly defined. Its width at Moscow is just two miles, while at Avon it is even more. Rock was found near Moscow at a depth of one hundred and eighty feet below the valley bottom, while four miles south, near Mt. Morris, it was found at a depth of one hundred feet.[1] The bottom of the valley is an almost uniformly level plain composed of fine material, with only here and there a hill of coarser sand and gravel, constituting what is commonly known as the "Genesee flats," and including some of the richest agricultural soil in the state. The supposition that this was an ancient lake bottom scarcely admits of any doubt. Professor Hall, arguing on this point, says[2]:—

"An examination of this deep deposit, on the Genesee flats, shows conclusively that it has been made in a lake, such as described, with a current passing through it from south to north. The deposit was evidently carried forward in that direction, as indicated by the lines of lamination. The coarser materials, at the points mentioned near the embouchures of the streams into this lake, are, in considerable proportion, of southern origin."

Professor Davis thinks that the cutting of this gorge from Portage to Mt. Morris and the filling of the lake from Mt. Morris to Rochester occurred at the same time, the one furnishing material for the other.[3] The sides of this valley have a gentle slope and are deeply drift covered, the rock being exposed only in the

[1] Kindly communicated by Mr. Clark Nichols of Moscow, N. Y.

[2] Report 4th geol. dist. N. Y., 1843, p. 344. See also 4th ann. report, 1840, p. 438.

[3] W. M. Davis, Proc. Bost. soc. nat. hist., v. 21, p. 359.

lateral streams. Fall Brook and Beard's Creek[1], entering the main valley from opposite sides, measure its width. These streams enter through short postglacial gorges at the head of which are perpendicular falls of sixty feet or more, formed by a hard layer of Portage rock capping the softer Genesee and Moscow shales. The sides of the valley as far as Avon are formed by the Genesee, Hamilton, and Marcellus shales, and on account of the soft nature of these shales they have been degraded to a considerable extent giving the valley its ill-defined outline.

Near Rochester the river enters upon its course through the final portion of its channel which is again a postglacial gorge seven miles in length, and cut into the Niagara, Clinton, and Medina rocks. In this gorge also are three falls, one at Rochester, ninety-eight feet high, over the thin lower layer of Niagara limestone, another of twenty feet over the Clinton band, and a third of one hundred and five feet over the hard, upper Medina sandstone.

Topography of the adjacent region.—An examination of the country on both sides of the Genesee reveals the existence of two other preglacial valleys, one on each side of the river. (See fig. 1.) These are occupied, however, by small streams only. The western valley first becomes well defined near Castile. From this point northward it grows more and more prominent until for several miles south and north of Warsaw, which lies in its center, it has the definition, width, and apparent depth, together with the flat bottom and drift-covered sides, of the valley south of Portageville. The rock is revealed in several lateral gorges near Warsaw, and consists mainly of the Portage shales and sandstones. Near the center of the valley, rock has been found at a depth of from one hundred and fifty to two hundred feet below the valley bottom.[2] The average width of the valley is one mile, which corresponds closely with the width of the valley south of Portageville. The bottom of the valley at Warsaw has an elevation approximating 1,000 feet A. T., while the top of the hill at the Erie Railway station is 1,326 feet A. T., the elevation of Portage Station being 1,314 feet. The Oatka, or Allen's Creek, a small stream emptying into the Genesee near Scottsville, occupies the

[1] These streams are similar in character to those entering Cayuga and Seneca Lakes through postglacial gorges, at the head of which are falls.

[2] Kindly communicated by Mr. L. E. Lounsbery of Warsaw, N. Y.

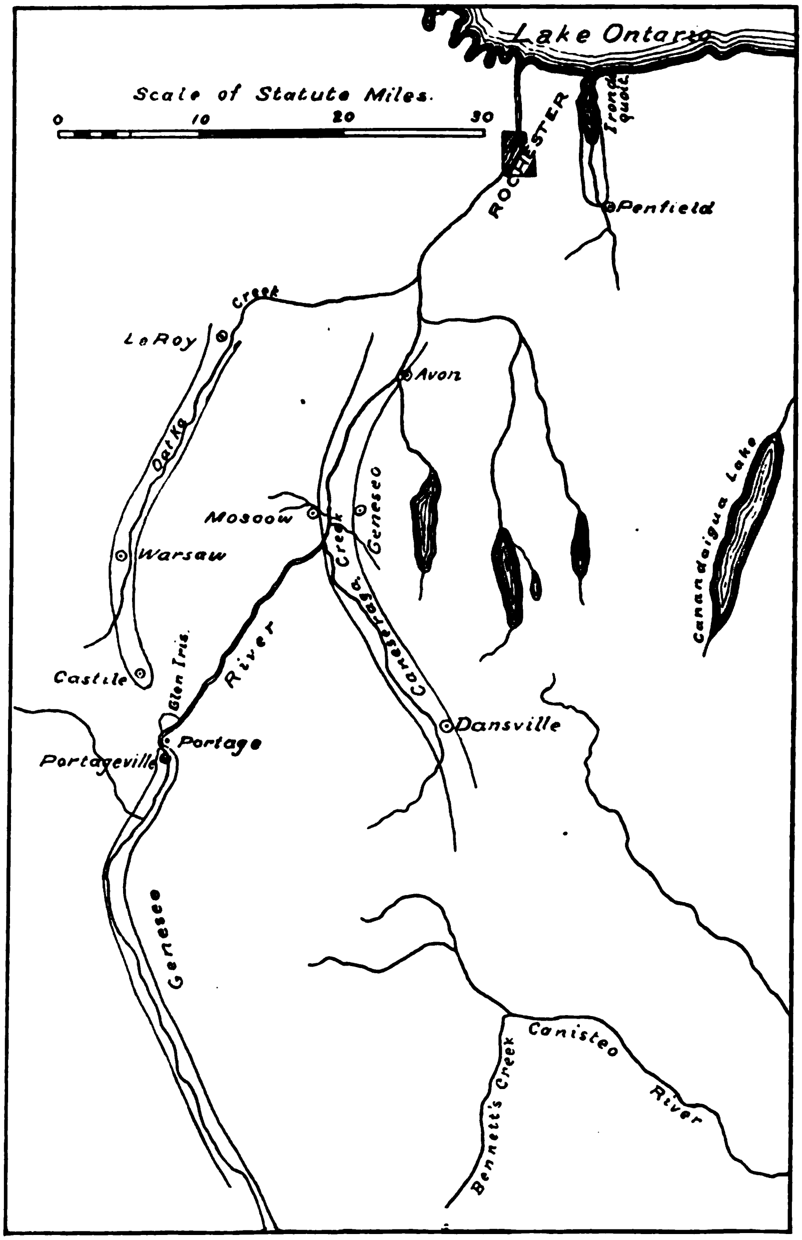


Fig. 1. Map of the Genesee River and its tributaries, with the preglacial valleys outlined, as far as traced.

center of this valley. At Le Roy and beyond, the outline of the valley becomes less distinct, owing to the softer character of the rock forming its sides, and to the more extensive deposit of drift material. Its continuation is presumably indicated by the Oatka, though this cannot be said with certainty.

The valley east of the Genesee extends from Dansville to Mt. Morris, where it joins the valley now occupied by the Genesee between Mt. Morris and Rochester, above described as the third portion of the modern channel. It is, in fact, a southward continuation of the latter; and, except that its sides are better defined, it has the same character, maintaining an almost uniform elevation of about 600 feet above sea level. It is to-day occupied by the Caneseraga, a small stream emptying into the Genesee at Mt. Morris.

For the sake of clearness in description it will be best to give each of these valleys a separate name. First, I shall apply the name Genesee Valley exclusively to the valley south of Portageville, in which the river flows to-day from its source to that village. Secondly, the valley from Dansville to Mt. Morris, and thence to Rochester, which, as a whole, is commonly called the "Genesee Valley", though only the northern half is occupied by the modern Genesee, I will call the Dansville-Rochester Valley. Finally, the valley in which Warsaw is situated I will call the Wyoming Valley, the name commonly applied to it, its major portion being in Wyoming County. The modern Genesee, then, has its first portion in the Genesee Valley, and its third portion in the Dansville-Rochester Valley, the other portions being in postglacial gorges.

Relations and Development of the Valleys.

Genesee and Wyoming Valleys.—In order to trace out the relations between these valleys it becomes necessary to look for the continuation of the Genesee Valley from Portageville northward. Standing at the head of the gorge opposite Portageville and facing in the direction of the river, we find on the right an immense deposit of drift material rising three hundred feet or more above the river bed. This deposit, which is in the form of a narrow, level-topped ridge, I will call the *Portage Ridge*. (See fig. 2.) Borings have proved the absence of rock to such a depth that, even without further proof, we should be warranted

in regarding this as the continuation of the preglacial valley. After entering the gorge, the first portion of which is cut into the left bank of the valley, the river again turns to the right, and,

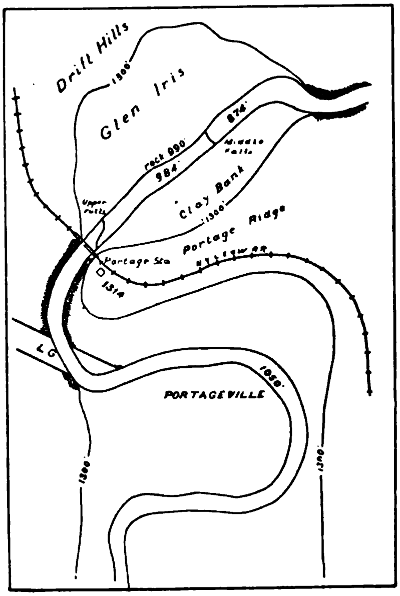


FIG. 2. Map of the Genesee River at Portage. From a compass survey. Scale 1 in. = 5000 ft. Shaded portions indicate rock exposure. L. G. Lateral drift-filled gorge.

ess than a quarter of a mile from the point at which it entered, it falls sixty-six feet, having described a horseshoe-shaped curve. Beyond this point the left bank recedes again from the river, leaving a plane tract of nearly a square mile at the river level. This tract, known as "Glen Iris," has the form of an amphitheatre, with hills on three sides and the river in the foreground. The right bank of the river, instead of being rock, is here formed of boulder clay with a covering of sand, this being, in fact, the other side of the "Portage Ridge" before noted. Here, too, can be seen the exact outline of the drift-filled portion of the valley, the rock, near the Upper Falls, sloping to the level of the river *below* the falls, and rising again, less than a mile down stream, that is, a little beyond the Middle Falls.[1] An examination of the hills

[1] Professor Hall in the report of the 4th district, p. 372, gives a description of this valley, with a diagram. He also speaks of it on p. 345.

in the background of the Glen Iris amphitheatre shows them to be composed entirely of loose material. Although, so far as I know, no borings have been made, the erosion and surface conformation of these hills seem to furnish pretty conclusive evidence of the absence of rock. Climbing to the top of the hills, which rise over three hundred feet above the river bed beyond the first falls, and looking towards Castile, it is possible to trace the connection between this point and the Wyoming Valley, which proves to be in the same direction with the Genesee Valley south of Portageville. It seems, then, very evident that Glen Iris is a portion of the Genesee Valley cut off from it by the "Portage Ridge," while the Wyoming Valley is a further continuation of this valley cut off from it by the more extensive drift deposit between Glen Iris and Castile. The modern Genesee, leaving its preglacial valley at Portageville, passes through a short gorge cut in the left bank; enters this valley again some distance beyond, crossing it at right angles from left to right in Glen Iris; and continues its way in a rocky gorge to Mt. Morris. Rock appears in the bed of the river below the first falls, this marking approximately the preglacial depth of the valley, which was about sixty feet lower than the bed of the river at Portageville or about nine hundred and ninety feet above sea level; hence the Genesee Valley at Portageville has been filled to a depth of about sixty feet.

Dansville-Rochester Valley.—From the foregoing considerations it becomes evident, that the Genesee was not the original occupant of the Dansville-Rochester Valley; nor had it anything to do with the formation of this valley, although, as will appear later, it had considerable to do with filling it. This valley is entirely distinct from the Genesee Valley and owes its existence to another river which flowed parallel to the Genesee at a distance of less than twenty miles to the eastward, and which was, like the Genesee, only one of the many northward flowing, preglacial rivers that characterized central New York, most of which, becoming permanently dammed up, have left their valleys filled with water, forming the "Finger Lakes." Of the character of the Dansville-Rochester Valley, Professor Hall writes as follows[1]:—

"The deep depression known as the Genesee Valley extends from Rochester, southward, as far as Dansville. Following the same direction

[1] Rept. 4th geol. distr., 1843, p. 343–344.

we find, after rising several hundred feet, that this valley communicates with the valley of the Canisteo River, and thence with the Chemung and Susquehanna. The Genesee River, beyond Portage, flows in a valley more than five hundred feet above the same, after leaving the gorge at Mt. Morris. The northern part of this valley, from Rochester to Dansville, maintains nearly the same elevation throughout, or with a gradual descent to the north. It is one of the most ancient valleys of excavation; and its sloping sides, covered with superficial accumulations to the height of 600 or 800 feet above its base, show an immense period of time to have elapsed since its formation. Long subsequent to its formation it has been partially filled with water, having a barrier on the north, and extending over the whole plain of the "*Genesee flats*," and south as far as Dansville, in one great shallow lake. At the same time the valleys south of Dansville and south of Mount Morris, by way of Cashaqua Creek, were discharging their waters into this lake. With these streams was brought down a large quantity of coarse and fine materials, which we now find about Dansville, and below the junction of the Cashaqua Creek, while the great extent of the valley is spread over with a fine sandy loam."

It seems quite probable that, as Professor Hall suggests, the valley was prolonged southward beyond Dansville, and that the divide between the head waters of the Canisteo and those of the Caneseraga is of later origin. Not having examined this region personally, I am unable to make definite statements regarding it. If the valley by way of Arkport and Hornellsville is the southward prolongation of the Dansville-Rochester Valley, we have our preglacial river of a length approaching that of the modern Genesee. This supposition seems to be favored by the character of several of the smaller streams, especially of Bennett's Creek which flows nearly directly north and joins the southeast flowing Canisteo by a short, sharp bend.

Perhaps the most appropriate name for this river will be the preglacial Caneseraga, since the valley from Dansville to Mt. Morris is to-day occupied by this stream. The distance between the preglacial Genesee and the preglacial Caneseraga was about eighteen miles at Dansville, and about fifteen miles at Mt. Morris. Seneca and Cayuga Lakes are eighteen miles apart at their southern ends, their shores approaching to within seven or eight miles near the center.

Condition of the valleys on the recession of the ice.—When the ice front had receded to near the southern margin of Lake Ontario, it formed a barrier across the northern end of the valley of

the Caneseraga, as well as across the northern end of the northern half of the valley of the Genesee, which had become separated from the southern half by the drift deposits at Portage and at Castile. A barrier near Rochester nine hundred feet or more in height would convert these valleys into lakes, the former extending back to Dansville and beyond, while the latter would reach south as far as Castile. The barrier formed by the "Portage Ridge" would likewise transform the Genesee Valley south of Portageville into a lake extending nearly back to its source. There would thus be three additional "Finger Lakes," each having an altitude of about 1,300 feet A. T. That these conditions actually existed is shown by the character of the valley-bottoms and by the subsequent history of the Genesee. Between the Genesee Lake on the south and the Wyoming Lake on the north, there existed a small lake occupying the Glen Iris Valley. This lakelet received the drainage from the Genesee Lake which overflowed at the point on the left bank where the short gorge commences which to-day connects the valley on the south with Glen Iris. This course was necessitated by the height of the drift deposits on either side, there being at this point a slight depression between them. Owing to the height of the drift hills which separated Glen Iris Lake from Wyoming Lake, no connection was established in this direction; but the surplus water, overflowing at the lowest point, took a course diagonally across the rocky plateau separating the two ancient valleys and entered the Caneseraga Lake at Mt. Morris. Thus commenced the wearing of that immense gorge which to-day extends from near the middle falls at Portage to Mt. Morris, with a total length of probably thirty miles, taking into account its sinuosity. As Glen Iris Lake was lowered by the deepening of this gorge a fall came into existence over the side of the valley, at the mouth of the short gorge carrying in the water from Genesee Lake. This fall has receded comparatively little since that time, being to-day under the railroad bridge which spans this gorge at its junction with Glen Iris Valley. The drainage of Genesee Lake was slow enough to admit of beach formations along its sides. On the final recession of the ice-sheet, the Caneseraga and Wyoming Lakes were lowered to near the level of the modern Genesee, the remainder being filled up. The Genesee was now the occupant of the northern half of the channel of the ancient Caneseraga which was

thus made tributary to it, having probably been reduced in size by the diversion of the drainage south of Dansville into the Chemung.

Outlets of the ancient rivers.—The former outlet of the Caneseraga seems to have been by way of the Irondequoit channel.[1] This channel, which is cut into Upper Silurian strata, extends ten miles backward from Lake Ontario and is in all respects similar to the other preglacial valleys, appearing to be of the same age; but, unlike them, it has probably been deepened by ice action.[2] The ancient Genesee, likewise, may have emptied into the Ontario Valley by means of this channel, joining the Caneseraga somewhere north of Avon, as is the case now with the Oatka or Allen's Creek.

Development of the lower gorge.—When the Genesee began to occupy the northern half of the valley of the Caneseraga, it found the outlet of this valley barred by drift; and, again overflowing the sides of the valley, which here were scarcely defined, it reached Lake Ontario by way of Rochester. As Lake Ontario subsided, a fall came into existence over the Niagara escarpment, which, travelling southward, was soon followed by a second and a third, as Lake Ontario continued to subside. The recession of these falls has left the gorge which now extends from Rochester to Lake Ontario.

A possible inter-glacial channel.—At the head of the great gorge opposite Portageville, we find another ancient drift-filled channel less than seven hundred feet in width and of unknown depth. This channel enters the Genesee Valley at an angle of 110°, its mouth being shown in the drift hill on the right bank of the river opposite Portageville. Almost at its beginning the present gorge cuts across this channel, exposing a complete section. The channel has the character of a drift-filled gorge, with nearly perpendicular sides; and this, together with the fact that it enters the Genesee Valley against the current, would seem to indicate that, at some time during a temporary recession of the ice sheet beyond Lake Ontario, it formed an outlet for the waters of Genesee Lake, probably carrying them into the Wyoming Lake and thus re-establishing the old drainage. The re-advance of the ice sheet would then block this gorge, and the outlet by way of

[1] A suggestion first made by Professor Hall.

[2] Dryer, Amer. geol., v. 5, p. 202.

Mt. Morris would be formed. From partial observation it appears that this gorge is filled by material of more local origin than that forming the Portage ridge in the main valley. Not finding any records of borings, I have been unable to trace the continuation of this gorge, the region here being covered by drift hills, which rise a hundred feet or more above the general level of the plateau. If, on the other hand, we regard this gorge as simply a tributary to the preglacial Genesee, we must consider it of late preglacial origin, in order to account for its perpendicular sides.

Summary.

To briefly summarize, this paper attempts to show the existence of two northward flowing preglacial rivers in western New York, parallel to the Seneca, Cayuga, and other rivers, whose valleys are now occupied by the waters of the Finger Lakes. These two rivers were the Caneseraga and the Genesee. Drift deposits compelled the Genesee to leave its ancient channel at Portageville and to cut across the intervening plateau to Mt. Morris, from which point it occupied the channel of the Caneseraga. Owing to drift deposits at Dansville, this latter stream lost a large part of its head waters, in consequence of which it dwindled, and virtually became a tributary to the Genesee. Finally is noted the existence of a lateral drift-filled gorge, which was either formed by a late preglacial tributary, or was of interglacial origin, temporarily re-establishing the northward drainage of the Genesee by way of Warsaw after the filling of the valley at Portage.

Note.—I take pleasure in acknowledging my indebtedness to Miss H. E. Freeman, for valuable assistance in the prosecution of the field work.

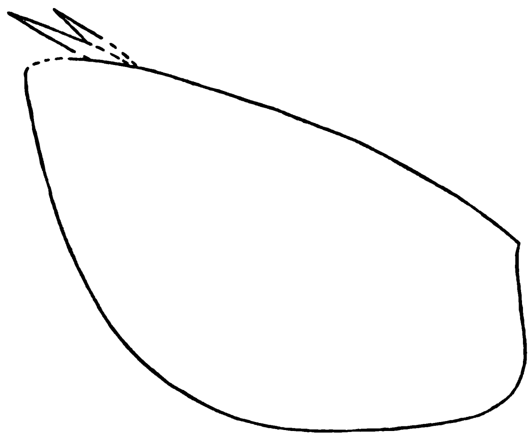
A SPECIMEN OF CERATIOCARIS ACUMINATA HALL FROM THE WATER LIME OF BUFFALO, N. Y.

BY G. W. STOSE.

The only specimen of this species previously recorded is a carapace described by Professor Hall in volume 3 of the paleontology of New York.

In June, 1893, I obtained a nearly complete specimen on a slab of the Water Lime strata from Buffalo, N. Y., which I will describe in detail. It is flattened on the rock, showing the side of the body. The carapace is detached and reversed in position.

The carapace is somewhat rhomboidal in outline, as can be

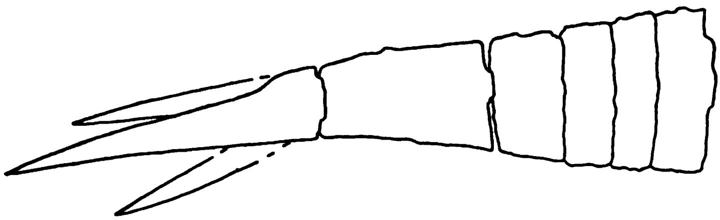


observed in the figure. Length between the extremities of the hinge line 4¼ inches. The maximum width at right angles to this, which is about at the middle, is 2½ inches. The posterior margin is slightly concave, curving sharply forward at the base. The anterior margin is nearly straight, and curves gently backward at the base. The dorsal margin is slightly convex, bending downward more sharply at both ends. The acuminate point in front, mentioned by Professor Hall, is not visible. The ventral margin is about at right angles with the posterior margin. The anterior and ventral sides are marked by a narrow raised border.

No ocular spot is visible. The surface is marked by fine curving lines, not shown in the sketch, running along the anterior margin and turning back parallel with the lower outline, the upper ones ending abruptly in the hinge line, the lower ones in the posterior margin. The majority show only under the lens, those along the anterior and basal margins showing more distinctly. Three quarters of an inch from the front end of the hinge, two slender, tapering appendages project upward and forward. These may be spines on the carapace, but more probably were antennae

of the animal projecting through the carapace where the valves diverge.

The tail shows five abdominal segments besides the triple caudal



spine at its extremity. The first segment is ½ inch long; second and third are each ⅜ inch; fourth is ⅝ inch; and fifth is 1¼ inches. The tail diminishes from 1¼ inches to ½ inch at the base of the telson. The first three segments are marked by fine lines parallel with the articulating joints, and turning abruptly backward near the margin. The spines are long, gently tapering, and sharp. The central one is largest, 2½ inches long, and is articulated with the fifth segment. The two smaller spines seem to articulate with the central one near its base.

THEORIES OF EVOLUTION.

BY EDWARD B. POULTON.[1]

In dealing with theories of evolution, I think that we shall all be agreed that we may leave out of consideration the question of the origin of life, and deal only with what has happened to life after its appearance, however that may have taken place. On this subject we shall probably most of us still agree with the opinion of Darwin[2], that we are not in a position to even speculate or think upon that question,—that any speculation about it is almost a waste of time. And this, I think, remains true in spite of the magnificent results of the organic chemists in producing chemical bodies by synthesis, which before had been regarded

[1] Read February 7, 1894.

[2] In Life and letters.

as capable of being made only in the laboratory of the living body. Many of these can now certainly be produced, but that is very different indeed from creating protoplasm endowed with life; and so far are we from achieving this by any chemical means, that I think we may venture to dismiss all consideration of the ultimate origin of life.

But granting the origin of living matter, these theories of evolution which we are considering and hope to discuss to-night can deal with it, and with their help we believe that we can account for what has subsequently happened; namely, the evolution of all forms of life, animal and vegetable, upon the surface of the earth.

The first of these theories which I propose to discuss is the well-known Darwin-Wallace theory of natural selection, with its three factors.

First, individual variation, — the fact that individuals differ, and that the differences are essential or inherent in the organism, so that even if animals were brought up alike, we know they would still be unlike, and so that, however much the offspring may resemble their parents, they are never exactly like their parents or exactly like each other. There is, then, first, individual difference, one of the most essential facts in the organism.

Secondly, the fact of heredity,— the fact that these inherent differences may be and are inherited. Although the hereditary transmission of acquired differences is disputed, the transmission of those that are inherent is certain. This stands before us as one of the most obvious and certain of conclusions, equally proved by the observation and experience of every one of us.

Thirdly, the fact that there must be a struggle for existence; that there are far more individuals born into the world in every species, even the most slowly increasing, than can possibly survive and reproduce.

These three factors must by logical necessity lead to a survival of the fittest among individual variations. It does not require a scientific mind to comprehend that, — to infer that some amount of evolution must ensue from the co-operation of those three factors, every one of which stands firm and undisputed. Among all the advocates of rival theories which have been brought forward to explain evolution, no one has ever ventured to attempt to disprove any one of these three factors. They stand unchallenged.

.Henry Fawcett, saw, long before scientific
understood what Darwin meant by natural
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said that natural selection must produce evolu-
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very successful attempt at scientific explanation only
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which natural selection itself depends; but because we have not yet reached that lower level, we have no reason for doubting, as some would believe, the complete efficiency, at its own level, of the explanation we do happily possess.

The theory which stands in contrast with natural selection, and which has been here supported more fully than in any other civilized country, with the exception of France, is the theory we usually attribute to Lamarck. Erasmus Darwin in England, however, has the priority, in that he first brought forward the principles which Lamarck more effectively supported. But to Herbert Spencer belongs the chief credit, because he has taken that part of the earlier theory which is acceptable to modern biological thought, and upon this basis has formed his great theory of evolution.

Lamarck believed in an innate tendency toward perfection in animals. Now, that is a view which very few zoologists at the present time, if any, would dare to sustain. In fact, an evolution due to an innate principle of perfection is not very much removed from the doctrine of special creation which preceded any theory of evolution. Herbert Spencer, therefore, rejecting all those elements of Lamarck, which the scientific world could not possibly accept, has taken that which has commended itself to science, and upon it has formed his great theory of evolution; so that the Lamarckian theory, as presented to the world to-day, comes before it in Spencerian language and in the closest relation to Spencerian thought. In saying this, however, I do not by any means intend to be understood as supporting Spencer's theories or the views upon which he bases them.

The Lamarckian theory, then, upon which Spencer has based his philosophy, is a theory of evolution dependent, not like natural selection upon three factors, but upon two. It depends first of all upon the effect wrought on the individual by that which happens during its lifetime. Instead of depending on those innate and essential differences upon which natural selection rests, this theory depends on those changes which are caused during the life of the individual,—the action of some external force upon it, the effect of its own will, the changes produced by the use and disuse of its own parts. The Lamarckian theory depends in fact on all those changes in an individual which we now call its acquired characters; that is, characters which the individual has

come to possess but which were not potentially present at the beginning of its separate life.

The first factor, therefore, is made up by changes that are wrought in this way. The second factor is heredity, by which it is supposed that these changes are transmitted; and it is certainly true that if such transmission is possible, some amount of evolution must result. You will all be prepared to admit that if these two factors represent facts, their co-operation must produce some amount of evolution.

It is important to remember, however, that both factors are not undisputed, as are the three factors of Darwinian evolution. Although we all admit the existence of acquired characters as the effect of external causes upon the individual during its life, yet biologists are by no means agreed that these effects are hereditary, and, if not, the acquired character ends with the individual in which it arose, and, not being handed on, can never become a character of the species. It is impossible for those wh hold the Lamarckian or Spencerian view to escape from this. If it is true that such characters are transmitted, then the foundation of the theory is secure; but the transmission of acquired characters is by no means proved. Herbert Spencer has preferred to occupy himself in rearing a magnificent edifice upon this foundation, rather than employ his acute intellect in testing its firmness and security in every possible way.

So far as observation goes, all those characters which are believed by many to owe their origin to the Lamarckian principle, are present in the individual before the beginning of its active life, before the operation of those causes which were believed originally to account for the characters. According to the Lamarckian theory such characters have already become hereditary; and therefore it is of essential importance to the Lamarckian to prove that acquired modifications can be and are transmitted. Only in this way can he give good grounds for the opinion that such characters, when they occur ready-made in the individual, are to be explained by the action of external causes during the lives of ancestors.

These are the two main theories of evolution. There are several others, upon which I will dwell only for a moment because these two alone command any very large amount of attention at the present time.

In the first place, Lamarck's theory of the innate tendency towards progressive perfection in animals is not held in exactly that form, but some zoologists in this and other countries believe that they see evidence in the rise and fall of certain groups of fossil animals for the existence of a tendency towards extinction, or a tendency towards sudden growth, which lies within the animal itself and is not determined by any external cause. That is a very close approach to Lamarck's original principle of an innate tendency in one direction or another. I will not discuss it at any length, because I think that this evening if we get some idea and have some discussion on the merits of the two main theories of evolution, that will be as much as we can expect. I will only say with regard to the subject that arguments based upon fossil remains are apt to be somewhat dangerous, because we have, at least so far as the conditions of life are concerned, so small an amount of evidence. In certain parts of Africa, for instance, the presence of the tse-tse fly absolutely limits the existence of some of the larger quadrupeds. Wherever that fly is, the animal cannot exist. It is very possible that in future times skeletons will be found in specially large numbers on the borders of districts where the fly abounded, and any attempt to argue, from the appearance of the skeletons themselves, as to the causes of this great extinction will obviously be entirely false and misleading. We have in the skeleton of an animal so small an indication of the events of its life and the conditions of its death, that it is, except in very rare cases, most unsafe to argue as to the causes of its extinction.

Another theory of evolution is one which has been brought forward by Professor Geddes of Scotland. He believes that there is an innate tendency towards growth and towards that dissipation of matter which constitutes its reverse, — the anabolic and katabolic tendencies, as he calls them. But that view, although he argues it with much eloquence, has not been widely accepted, and I think it will be generally admitted that it does not yet rest on sufficient proof.

In addition to these, there are some who maintain the position that there is an unknown cause of evolution. They believe that these theories, although one or more of them may be of value, are yet insufficient to account for organic evolution. Those who take this line are of course logically bound to bring forward the

classes of facts with which no existing theory is, as they maintain, competent to deal.

All we shall have time for to-night is briefly to compare natural selection, the Darwinian interpretation of evolution, with the Lamarckian theory. It is interesting to note that, although they are so essentially distinct one from another, in earlier times these two theories appear to have been entirely confused. Lamarckian evolution, Spencerian evolution, appeals to the mind of man far more strongly than Darwinian evolution. Any one of us, were we to have created the organic world, would certainly have created it according to Lamarck. We should have made evolution by use and disuse of parts, and not by natural selection. However, we are not concerned with the sort of world that we should have created. The question before us as scientific men is not what might have happened, but what has happened. Nature, as I have heard Prof. Michael Foster say, has a very queer way of going by roundabout paths and refusing to take the roads we should lay out for her ourselves, and which we look upon as the most direct and obvious. The fact that the general aspect of the Lamarckian theory commends itself to the human mind affords no reason for looking upon it as the correct one, as opposed to the Darwinian theory.

The Duke of Argyle, who is still strongly antagonistic to natural selection, a few years ago wrote an article in the Nineteenth century called "The power of loose analogy." By this title he intended to imply that those who believe in natural selection have been led away by the specious character of the words themselves. I suppose that the Duke feels himself bound to account in some way or other for the fact that people believe in natural selection, while he does not, and accordingly he suggests that the seductive power of the title employed by Darwin has misled the scientific mind into a belief in the process itself,—only rare and subtle intellects like his own being proof against such an allurement. *Natural:* a word expressive of familiar objects and processes always around us. *Selection:* a process with which we are all familiar. In this way it seems reasonable to the Duke of Argyle to suppose that men have been misled by the seductive nature of the terms employed by Darwin. The terms applied to processes familiar to every one, and therefore every one accepted them at once, without inquiring what they

really meant. This is, of course, an explanation eminently satisfactory to the single writer who was not to be convinced by "the power of loose analogy." But when we proceed to test this ingenious suggestion, and look into the history of the times to which it applies, when we read Darwin's letters, we find that he continually complains that people do not understand what he means by natural selection, and he almost regrets having used these words. He says more than once that he wishes he had used Herbert Spencer's term, the survival of the fittest, because his own title, natural selection, is comprehended with such difficulty.

When we look to another class of evidence we find equally sure ground for the conviction that natural selection was driven into men's minds with the very greatest difficulty, and by no means with the ease which the Duke of Argyle assumes. It is very interesting to consult the various skits written between twenty and thirty years ago, and in which the writers supposed that they were making fun of Darwin's theory. If you will read them, you will be struck by one very remarkable fact: their authors are all making fun of Lamarck when they believe they are making fun of Darwin.

I remember once seeing a picture in Punch, representing the evolution of the power of flight by the human species. It represented a man standing upon the roof of a house and waving his hands, which, in consequence of the use to which they were put during his individual life, grew somewhat in size. Passing down to the next generation, his son was found waving rather larger hands, and the waving made them still larger. In the course of generations the descendants acquired large wings and flew down from the roof of the house. That was supposed to be a parody on evolution according to Darwin. I have called it a skit, but you will see at once that you cannot get a better illustration of Lamarckism. It *is* Lamarckism. It is not making fun of it; it is a description of the process itself.

Then Lord Neaves wrote a song in which he attempted to make great fun of Darwin's theory. It was a very long song, many verses of which were skits upon Lamarck, while supposed to be skits upon Darwin.

> "A deer with a neck that was longer by half
> Than the rest of its family's — try not to laugh —
> By stretching and stretching became a giraffe,
> Which nobody can deny."

This is pure Lamarckism. The evolution was supposed to be caused by stretching without any selection at all.

The best example of all, however, is given by Mr. Courthope, in his "Paradise of birds." I commend his account of the evolution of birds and mammals to those who believe the Lamarckian theory. He tells us there about the Ornithorhynchus, which he commends as a very prudent beast:—

"For he saw in the distanse the strife for existence,
That should his grandchildren betide,
And resolved, as he could, for their ultimate good,
A remedy sure to provide;
With that, to prepare each descendant and heir
For a separate diet and clime,
He laid, as a test, four eggs in his nest,
But he only laid two at a time.
On the first he sat still, and kept using his bill,
That the head in his chicks might prevail;
E'er he hatched the next young, head downwards he slung
From the branches, to lengthen his tail.
Conceive how he watched till his chickens were hatched,
With what joy he perceived that each brood
Were unlike at the start, had their dwellings apart,
With distinct adaptations for food.
From the bill, in brief words, were developed the birds,
Unless the tame pigeons and ducks lie;
From the tail and hind legs in the second-laid eggs,
The apes and—Prof. Huxley."

If we now turn to the skits on evolution written at the present day we find they are very different. Miss May Kendall, in writing her "Ballad of the Ichthyosaurus," only a few years ago, says:—

"E'er man was developed, our brother,
We swam and we ducked and we dived,
And we dined as a rule on each other;
What matter? The toughest survived."

This is true natural selection. The authoress understood what she was talking about. And even long ago, at the time when those mistaken parodies were written, intended for Darwin and really applying to Lamarck, we find an acute mind like that of James Russell Lowell, in the Biglow papers, making fun of Darwinian evolution:—

"Some flossifers think thet a fakkilty's granted
The minnit it's proved to be thoroughly wanted,
Thet a change o' demand makes a change o' condition,
An' thet everythin' 's nothin' except by position;
Ez, fer instance, thet rubber-trees fust begun bearin'
Wen p'litikle conshunces come into wearin',
Thet the fears of a monkey, whose holt chanced to fail,
Drawed the vertibry out to a prehensile tail."

That is a most ingenious and interesting parody, making the theory of natural selection apply to the individual instead of to the species. The writer pretends to suppose that a quality is gained in the course of the individual life, because of the individual need; whereas under natural selection it is gained in the course of many generations by a need which is imperative enough to cause the extinction of individuals without the quality, or with it in a comparatively slight degree.

Another interesting question has been raised by Mr. Lloyd Morgan, as to whether the phrase "natural elimination" would not be a more correct one than "natural selection." The process is, of course, selection by and through elimination. The survival of the fittest means the elimination of the unfittest.

The relation between selection and elimination has been put in a very striking way by Mr. Samuel Butler, who says that according to natural selection we are what we are, not by the successes of our fathers and mothers, but by the failures of our uncles and aunts. The question is, shall we dignify with the title of this important cause of evolution those who have failed in the struggle, and do not happen to be the ancestors of any living species, or those who have succeeded in the struggle and are now abundantly represented by descendants? I think that "natural selection" forms on the whole the best term for the process. It has the advantage, also, of being the historic term proposed by Darwin.

Another important point in favor of "natural selection" as a term, is that it suggests a parallelism or comparison with the process of artificial selection. Yet another point is the fact that you may find in the words themselves all the three factors obviously suggested; for selection would be impossible without individual difference, and it would be useless unless these differences were hereditary; and, furthermore, selection implies something which selects; that is to say, the conditions of nature,

the rate of increase with its result, the struggle for existence. So that the three factors of natural selection are implied by the very words themselves.

Now I want very briefly to bring forward the chief objections that have been urged against natural selection. In the first place, if natural selection be true, all the varied characters of animals and plants must prove to be useful to the possessor in the struggle, or to have been useful at some time in its history.

We are only required, however, to prove utility as regards undoubted characters of the species, and these are hereditary, and we must put on one side certain characters which are confined to the individual in which they appear. For instance, if it were proved that the Mollusca of any one river differed from those of the same species in another river, but that the differences were confined to the individuals in which they occurred, so that if these Mollusca were placed when young in the second river, they would come to resemble those which were proper to it, then we should not be concerned with characters of the species at all. The language spoken by a nation similarly is not a character of the human species, for we know that a child of another nation would acquire it perfectly together with the particular modes of thought and expression tortuous or direct which are associated with it. These results of environment are not characters of the human species. The individuals of the human species come into the world with a certain elasticity, a certain power of being developed in various directions. But although the elasticity itself is a character of the species, and is inherent, the particular quality in which it may result when operated upon is certainly not a specific character.

The more we work on the characters of animals in general, even though we at first can see no utility, the more we come to admit this principle, and to believe that either now or in some past time, the characters have been useful. I can certainly say of many characters which I have studied in some of my investigations, that at first they seemed to be meaningless, but afterwards appeared to be of much importance in the struggle for existence. I think we may safely assume with regard to many characters of which we can now see no explanation that by and by the explanation will be forthcoming.

Being unable to prove utility does not invalidate natural selection. If inutility could be proved for any large class of characters, the theory would certainly be destroyed as a wide-reaching and significant process. I do not think, however, that any such evidence has been forthcoming. I shall be interested in the discussion which follows this paper to hear whether those who believe in the Lamarckian theory have any such evidence to produce, whether they can prove that any one great class of characters has been useless in the past and remains useless in the present.

Another class of objection has been urged long ago, and is still urged to-day. Why do we not find in the paleontological series the records of failures? Now, as regards the individuals of a species we cannot expect to find any such evidence. What is failure? Failure means, according to natural selection, the failure to produce offspring. The individual which comes into the world and dies young has failed. The individual which is represented in the generations of the future has succeeded. Natural selection has set its stamp upon that individual. But it is impossible to say whether or not this is true of any particular fossil. We have not got the facts before us by which we can form any conclusions.

Furthermore, we know the struggle for existence is excessively complicated. The skeleton *alone*, though of the highest value in association with the rest of the organism, has been the turning point in the struggle in a comparatively small number of cases. When it has been the turning point in association with other parts, these latter are absent. We have only a very small part of the problem before us, and never can expect any more.

But while we cannot expect to find evidence of the survival of the fittest among the individuals of a species, we may expect to find it in the supplanting of classes by classes, of groups of species by groups of species. Some of the facts which have been brought forward as evidence in this direction do, to my mind, very strongly support the theory of natural selection by paleontological evidence. Consider especially the case of the large mammals preceding those which gave rise to the quadrupeds now upon the earth. So far as we can judge of these huge forms by their skeletons, they appear to have possessed a bodily structure as well fitted to survive as that of many now living in the world;

but they differed from these latter in that they had extremely small brains. We can easily understand that inferiority of intellect would cause them to be worsted by animals which were in other respects no better endowed.

Exactly parallel is the relation of man and the apes. In bodily structure the difference is insignificant. In the brain, however, we meet an important and essential distinction. It would appear here that natural selection has taken one particular part of the organism of paramount importance in the struggle, and has developed that rather than made a change along the whole line.

We see the same relationship in the gigantic reptiles of the secondary period as compared with the mammals of the Tertiary. The latter with their larger brains and higher intelligence were able to supplant the former, just as they have in turn been supplanted by the still larger brained animals whose descendants now people the earth. All this seems to me to afford very strong support to the theory of natural selection.

Passing now to another class of objections: natural selection, it is said, can never account for the beginnings of things. Until an organ is raised to a useful level, selection can have nothing to do with it. At first sight that is a serious objection, but it suggests its own answer; viz., that an organ so rarely develops *ab initio*. Organs are not formed anew in an animal, but they are formed by the modification of pre-existing organs; so that, instead of having one beginning for each organ, we have to push the beginning further and further back, and find that a single origin accounts for several successive organs, or at any rate several functions instead of one.

The typical vertebrate has four limbs. These in fishes are used for swimming, while in terrestrial forms the same limbs are modified and used for walking. New organs are not introduced, but the old are modified for a new purpose. When the terrestrial form again becomes aquatic, the limb that was used for terrestrial progression is modified back into a functional fin; and again, when flight becomes necessary, the same organ is used for the new function. So that whatever the changes in the mode of progression, we need no new organ at all; for the old organ is used for the new purpose. It is very much easier to understand how a useful level can be attained in that way than by organs starting *ab initio*. But of course we must come down to a true

beginning if we push our inquiries far enough. In attempting this, we are carried to those remote times in which the ancestors of vertebrates arose. Upon these forms we can do no more than speculate, but it is at any rate impossible to prove that four bud-like projections from the body may not have been useful, from their very beginning, to a slender worm-like animal in pushing its way through mud or thick weeds. Dr. E. B. Tylor has told me that he believes that the same thing holds with regard to human weapons. He said that, in examining ancient weapons, he was often struck with the fact that a weapon or implement had ultimately turned out to be so very much more useful for a new purpose rather than that for which it was originally formed. Here, then, one origin apparently accounts for several forms of implement.

Another objection raised against natural selection is that a selective cause is never a true cause. Professor Cope means to imply that when he speaks of the "*Origin* of the fittest." But Darwin's argument on this point is perfectly sufficient. He says that when a man drops iron into sulphuric acid, he does not originate the chemical force that operates, but he may be fairly said to make sulphate of iron. So natural selection does not itself originate the factors upon which it depends, but it is so essential to the result that it may be fairly looked upon as the true cause (at that level of causation). In Galton's work we have a most complete inquiry into human variation and its inheritance, and he shows us that such variation by itself, unguided by selection, can never advance to anything. Even if you start with ancestors who are remarkable for any intellectual or structural feature, their descendants, although some of them may partake of their parents' peculiarities, sometimes even to an increased extent, will ultimately return to the pattern of the race. There is always a "recession towards mediocrity." Hence, unguided variation can never explain the "origin of the fittest." Such a view is entirely contradicted by the results of Galton's researches. Any marked change in the direction of fitness can only become a character of the species by accumulation through many generations, and this can only take place by natural selection. Variation unguided by selection can never advance on the increase of fitness present among the individuals of a single generation; and even these improvements, if relatively marked, can never become

a character of the species without selection, but by recession will tend to be lost in the subsequent generations.

I have briefly touched on some of the chief difficulties which are advanced against natural selection. I now propose to devote the remaining part of my time to the difficulties which seem to me to apply to the Lamarckian theory.

Lamarckian evolution, as I have mentioned before, depends upon acquired characters. A good deal of misconception has arisen from this use of the word "acquired." An acquired character has sometimes been interpreted to mean any character that an animal has come to possess; hence, inherent and acquired characters have been confused. The word "acquired," as used by biologists, must be understood to have a limited and special application, meaning only those characters which have been produced in the organism by the incidence of external forces, or by the action of its own forces, use and disuse of parts, and so on, during its life. Weismann has suggested the term "blastogenic" for characters potentially present in the germ at the very beginning of life, and "somatogenic" for those which appear afterwards and are not potentially present in the germ. Here blastogenic is the equivalent of inherent, and somatogenic of acquired.

Some years ago I suggested that the terms "centripetal" and "centrifugal" might be employed to express this acquired difference, acquired characters being centripetal, because they are impressed upon the body or one of its parts from without; inherent characters being centrifugal, because, arising from within, due to the essential nature of the organism itself, in the course of development they come to appear, as it were, on the surface as visible features.

When we now consider the transmission of acquired characters, upon which the Lamarckian theory certainly depends, we are led first of all to inquire whether it is possible to frame a theory of heredity within which such transmission can be included. If, for instance, there is a change in the brain of an animal, owing to the exercise of some part of it, how can such a change in the brain-cell be transferred to the germ-cells of the animal, so as to be transmitted to its offspring? It may be objected, if you can prove that such transmission does take place it is no matter how it takes place. Quite true, if the evidence is sufficient and indisputable. But we must remember that the amount of evi-

dence required in order that there may be sufficient, depends upon the probability or improbability of the thing to be proved. This view is extremely well put by Professor Huxley in his memoir of Hume, where he says that if any one came to him and stated that he had seen a piebald horse in Piccadilly he would be prepared to believe it; that he might require confirmatory evidence if the statement were that a zebra had been seen; but that if even the friend in whom he trusted told him he had seen a centaur trotting down that eminent thoroughfare, he should emphatically disbelieve it, and that nothing short of a monograph on the anatomy of the centaur by a comparative anatomist of the stamp of Johannes Müller would convince him that the observation was correct. We are compelled to admit that the amount of evidence we require does to a great extent depend upon the inherent probability or improbability of the conclusion to be sustained. If it appears to us to be almost impossible to conceive of a mechanism whereby an acquired character can be transmitted from the outlying parts of the organism to its germ-cells, then we have every reason for scrutinizing most carefully any evidence that is alleged to prove such transmission.

Let me first of all give you a concrete example which is frequently brought forward by those who believe in the Lamarckian theory in this country, and have chiefly studied the skeletons of Mammalia. They say the joint of an animal possesses just the sort of shape that would be produced by the motion of the joint itself, and they urge that the joint as we see it has arisen from the hereditary effects of that motion. They look upon this as a very satisfactory explanation, because they consider it to be so obvious and fundamental. You do not require anything further, selection is unnecessary and even the individual variation—so mysterious a factor of the Darwinian theory—is here entirely explained.

But is the interpretation valid? In the first place, it is clear that such an hypothesis can never afford a wide or general explanation. There are a great many parts of the animal body which are not modified in their use. You cannot thus explain the growth of hair, or the color upon the surface of the organism. For these and other useful but passive structures, the Lamarckian interpretation will not hold at all. Hence we may divide the organism into two sections, to one of which the Lamarckian

theory might be held to apply, and to the other the Darwinian alone.

But upholders of the Darwinian theory consider that it applies to the other section as well. They point out, that while the form of the joint is the sort of form that would be produced by the motion, such a form is the only one which admits of convenient motion, that motion has been essential to the life of the organism, that alert and rapid movements have been a necessity in the struggle for existence, and that any form which would prevent or clog the movements would be at once destroyed by the operation of natural selection. Natural selection they hold to be competent to explain these parts which the Lamarckians also claim to explain, while it offers the only explanation of the other parts.

If we suppose that Lamarckian evolution in part explains the actively used organs, and Darwinian evolution in part, we should expect that modification would take place more quickly in that section of the organism where the two principles were at work than in the other section where only one principle—the Darwinian—can play a part. But there is no evidence of such especially rapid evolution. It seems to me that we are in a position to use the old principle of cutting off superfluous causes. No unnecessary cause should ever be introduced into an explanation, and if Lamarckism, untenable in the one section, is superfluous in the other, it should be removed, unless there is very clear evidence proving that it has been at work.

Furthermore, in certain cases, such as the protective attitudes and appearances assumed by many animals, we meet with clear evidence that the two kinds of parts—those that are effected by their use and those that are not affected—have undergone development together, suggesting strongly that their evolution has been under the direction of one set of forces, and not of two sets which have little in common.

Having now brought forward certain general objections to the Lamarckian position, let me take exception to one or two special cases.

Certain animals, such as lobsters and crabs, have the power of very readily parting with some of the most important of their members. The large claws are easily thrown off, and this may be of great advantage in the struggle of life, because when an

individual is attacked by an enemy and seized by the claw, it has a chance of escaping. In the case of the lobster, the dismembered claw may not let go of the enemy although the enemy may let go of the claw. The claw may take charge of the enemy while the lobster escapes.

Now that is a very interesting adaptation. We find the claw so formed that it can be thrown off, but even when thrown off it continues to be of much use to the organism. Its nervous and muscular mechanism is so arranged that mutilation actually stimulates it to contract, and it continues to hold the enemy. In the case of certain crabs, the dismembered claws keep snapping and jumping about. The same is true of the tails of many lizards, which, when thrown off, will jump about in the most active way, distracting the attention of the enemy, while the lizard makes its escape. Here, too, mutilation stimulates the nervous and muscular mechanism in tail and claw.

In these cases of actively used parts of the organism the Lamarckian interpretation is absolutely at fault. You cannot apply it. It is impossible to explain upon the theory of the transmitted effects of use and disuse. No activity manifested by the tail after it has ceased to be part of the lizard can ever be transmitted. Not only that, but all development undergone by the tail from the effects of use and disuse, etc., up to the time of its severance, is also lost to the individual, and cannot be hereditary. And so with the claw. The large claw is the most important appendage of the lobster, and yet it is probable that most lobsters lose it many times and grow a new one. We have here a very specialized organ with very remarkable functions continuing in ever an increased degree after severance from the animal; all this is readily explained by the Darwinian theory, but cannot be explained by the Lamarckian.

The same inadequacy of the Lamarckian theory is forced upon us when we look a little more deeply into the nature of the process which is supposed to occur. The Lamarckians attempt to explain joints and some other structures by the effects of stress and pressure, but when we look into the matter a little, we find that the explanation is not so complete as it is supposed to be.

For instance, it has been believed in this country by many distinguished biologists that the complex shape of mammalian teeth is due to pressure produced by mastication. As the pressure

has been applied to the tooth, so has the tooth grown. But would pressure produce such an effect upon a tooth? That is certainly not our experience. Pressure and friction have an unfortunate way of wearing a hole in the tooth, rather than causing it to grow an elevation. As a matter of fact we know that the shape of teeth is predetermined long before they are cut in the soft dental matrix beneath the gum. It is not a question of the transmission of acquired characters, but the supposed transmission of a character which the parent cannot by any means acquire. Teeth, so far as they react to pressure or friction can only react by wearing away. With regard to the joint, we are told by some Lamarckian writers, that pressure and friction produce the reverse effect and wear away cavities rather than cause new growth.

I was reading a most interesting paper by Dr. Wortman of New York, the other day, attempting to explain the occurrence of a furrow in a joint, owing to the pressure of a corresponding ridge. The pressure of the ridge, it was said, produces a furrow in the opposite side of the joint. It seems to me that in this we are going a little beyond what physiology and histology teach us. It seems to me to be a blind appeal to mechanical forces unsupported by any adequate investigation of the physiology and histology of the tissues concerned. Is it likely that a bone would react to intermittent pressure by producing a furrow? It is far more probable that the reverse effect would tend to be produced.

I will only ask one more question with regard to this matter of use and disuse, and that is, why, if you are going to explain any of these parts by pressure and friction, should the process be stopped when a useful level is reached? If the pressure does cause such effects and they are hereditary, how are they prevented from increasing beyond all bound in the course of generations? Why should pressure on teeth cease to produce further growth, when the tubercle has reached its proper height? It seems to me that the fact that all these shapes of bones and teeth just reach and stay at an adaptive level is the strongest evidence that they are not produced by the operation of mechanical forces, but by natural selection.

We now pass to the consideration of indirect evidence: that it would be impossible to explain evolution without the Lamarckian theory.

Time will permit me to deal with only one class of characters, and that is associated with the nervous system and manifested as instinct. These instinctive actions are generally thought to be the strongest evidence in favor of Lamarckian evolution. It has been argued that we cannot explain the instinctive action of animals — the wonderful instincts which are due, as we know, to modifications of the nervous system, — except by supposing that animals have intelligently modified their actions in consequence of experience and observation, and that the result has then been transmitted and has become the non-intelligent instinct of their offspring. If we had no other explanation of instinctive action, such an interpretation would constitute a strong support to the Lamarckian theory.

I do not, however, believe that this is the only, or, indeed, the correct explanation of instinct. In considering this question, we must distinguish between the instinct manifested by many of the higher invertebrate animals and much that we are apt to call the instinct of the vertebrates. A great many actions which are put down to instinct in the higher vertebrates, such as birds and mammals, are not instinctive at all, but merely the result of observation during the life of the individual. We see an example of this in the action of the seal which, as Nansen tells us, took up a position on the outer ice-floes to escape the dangers of the polar bear, and afterwards incurred this very danger on the inner floes to avoid the greater peril from the hunter. This is a clear case of reasoning from the results of observation, and no instinctive avoidance of danger. So also with a bird which flies away if you have a gun in your hand, but allows you to come near when you have a walking-stick. This is the result of reason and not merely instinct; and we must carefully distinguish between a lesson learned by the individual, however well learned and easily repeated it may be, and a true instinctive action which was never learned at all but sprang fully formed into existence. Such true instincts certainly occur in the higher vertebrates, such as the act of sucking performed so perfectly without any education or practice by the newly born mammal. In the lower animals such true instincts are relatively far more numerous and play a most prominent part in the life of the individual. In these cases of true instinct I would suggest that we are dealing with actions which have never been intelligent at any time in the past history

of the species, and which have been due to the operation of natural selection upon the nervous system. Certain cases which are most strongly held to be the outcome of the transmission of gained experience and the acquired results of practice certainly cannot be explained in this way.

For instance, how upon any such hypothesis can you explain the wonderful structure of the cocoon spun by the larva of an insect? The view would be, I suppose, that the ancestral larva spun a cocoon which was not much of a success and was in consequence attacked by enemies; that the larva observed these attacks, and accordingly improved its cocoon. But that is not the way in which the struggle for existence is waged with insects. If the larva failed, it failed, and that would be the end of the matter. It has no chance of improvement; it has no opportunity of learning by experience. Its only chance of survival is to avoid experience of foes altogether; experience is the most dangerous thing in the world to an edible insect. This becomes still more obvious when we remember that failure or success is almost always determined long after the cocoon is made. The caterpillar perhaps spins the cocoon in autumn, but the real stress of competition will come in winter, when insect-eating animals are pressed hard with hunger and search high and low for food. But the caterpillar by this time is a chrysalis and of course has no opportunity of improving the cocoon. The selective test is applied long after the operation has been performed, and when there is no possibility of gaining by experience. We are thrown back, then, solely upon natural selection, which acts on the nervous system of the caterpillar, and thus compels it to make the cocoon in a certain way. In other words, those caterpillars which are impelled by their nervous system to make ill-formed, conspicuous cocoons have no chance of living, and in future stages producing offspring. Hence, the selection caused by the keen sight of foes first raises and then maintains at a high level the standard of cocoon-making.

This contention as to the uselessness and danger of experience applies to the whole of those smaller defenceless animals which have no chance of fighting with their enemies or of escaping when once they have been detected.

Another special kind of instinct has been greatly relied on by Romanes as evidence for the Lamarckian theory of transmitted

experience. Certain Hymenoptera allied to wasps possess an instinct which leads them to sting larvae and store them up in their nests as food for their young. It is generally believed that the larva is stung in the central part of the nervous system so that it can no longer struggle. I say "generally believed" because it has been pointed out to me by so distinguished an observer as Dr. Peckham of Milwaukee, that certain facts are opposed to the generally received account. It is to be hoped that the observations which are chiefly due to Fabre will be repeated and tested as minutely as possible. The prey is stored up in the mud-tube or burrow of the hymenopteron, and keeps perfectly fresh because it is alive, although completely paralyzed. Larvae stored up in this way appear to live much longer than those which, in the full possession of their faculties, are deprived of food.

Now this is a very wonderful instinct, and it has been argued that here is a case which cannot be explained except on Lamarckian lines. I maintain, on the contrary, that it is a case which cannot by any possibility be explained on Lamarckian lines.

The wasp-like insect has no opportunity of learning by experience because it can never know whether the larva stored up is a failure or a success. If the larva had not been stung, or, accepting the received accounts, had been stung in the wrong place, it would struggle and perhaps kill the young grub; or dying of starvation it might dry up and be useless as food. But the hymenopteron never goes back to inquire. It makes all the difference to the young grubs whether the food provided for them is in an appropriate condition or not, but it makes no difference whatever to the parent insect. The latter seals up the chamber in which its eggs have been laid and never opens it again; it has no chance of noting the failure or success of the food it has provided. It is clearly a case like that of the cocoon which cannot be explained on the Lamarckian theory and must be explained on the Darwinian. And this latter interpretation is easy: those insects which possessed the nervous mechanism impelling them to provide food in an appropriate condition gave to their offspring the opportunity of surviving and inheriting the same instinct. While others, impelled to perform less efficient actions, were thereby cut off from any representation in the next generation.

If the origin of wonderful and complex examples of instinct such as these cannot be explained by the Lamarckian theory but readily by the Darwinian, why should not natural selection also offer an adequate explanation of all other cases?

I have already taken up a great deal too much of your time. I much hope to have the opportunity to-night of hearing many stronger arguments in favor of the Lamarckian theory than it has been my opportunity to hear hitherto.

Note. — In revising the short-hand transcript for publication, I have not made any changes which alter the character of the address. It remains the record of a spoken address, the sequence and continuity of which were maintained by the use of brief notes. I have not verified the quoted opinions and words of others, and there are probably verbal errors. I believe, however, that in every case the true meaning of the author has been preserved. — E. B. Poulton. Oxford, May 21, 1894.

General Meeting, November 7, 1894.

President W. H. Niles in the chair. One hundred and nine persons present.

The President announced the death of Prof. Joseph Hyrtl, an Honorary Member since October 20, 1858, and of Dr. Oliver Wendell Holmes, a Member since April 6, 1831.

It was announced that the following Corporate Members had been elected by the Council: Miss Katharine Foot, Messrs. E. A. Bangs, E. E. Fernald, E. D. Spear, and G. E. Stone.

The thanks of the Society were voted to Prof. Jules Marcou for the gift of his manuscript geological map of North America.

Prof. George L. Goodale gave an account of the Ware collection of Blaschka glass models of flowers in the Harvard university museum.

The following paper was read: —

DESCRIPTIONS OF CERTAIN LEPIDOPTEROUS LARVAE.

BY HARRISON G. DYAR.

Family NOTODONTIDAE.

LOPHODONTA FERRUGINEA Packard.

Egg. — Laid singly, usually on the upper side, near the middle, of the leaf of its food plant (*Betula papyrifera*). Rounded, somewhat flattened, about the shape of two thirds of a sphere with flat base; diameter 1 mm., height 0.6 mm. Slightly shining, fine turquoise-blue or more rarely of a greenish blue tint. Microscopic reticulations neatly defined, but rounded, scarcely angular, becoming small and indistinct at the micropylar region. On the sides the reticulating edges of the cells become broad, flat, almost like bands, reducing the enclosed depressions to shallow pits. Found during the early part of July at Keene Valley, Essex Co., New York.

First larval stage. — On hatching the larva leaves the shell largely intact and takes up a position at the extreme apex of the leaf where it eats the upper epidermis and parenchyma. Head cordate, entirely shining black; width 0.6 mm. Body rather bright greenish yellow, thoracic feet black, cervical shield transverse, dusky. Setae fine, short, black, distinct but without evident tubercles; not glandular; 1 and 2 nearly in line, 3 above spiracle, 4 substigmatal posteriorly, 5 subventral anteriorly, 6 absent as usual in the first stage. Feet all used; leg plates concolorous with the body. No anal plate. Length about 3 mm.

Second stage. — The larva eats away the substance from the midrib of the leaf at the apex, using the midrib as a perch on which it rests. Head slightly bilobed, greenish; a smoky black shade covers the side including the ocelli, and a narrow smoky band reaches the apex in front of the lateral angle; mouth brown; a few setae; width about 1 mm. Body cylindrical, smooth, feet normal, all used. Thoracic feet and leg plates black except the anal pair. Setae short and fine, dark, from minute black tubercles, very inconspicuous; arrangement normal, 6 present. Body green with very faintly indicated addorsal, subdorsal, lateral, and superstigmatal waved whitish lines. Spiracles pale.

Third stage. — Head rounded, flat before and held out flat; leaf-green; a smoky black band behind ocelli extends backward and upward to the side of the head where it ends tapering; mouth reddish; width 1.6 mm. Body as before, but the fine dark setae have no tubercles. Color pale leaf-green; on joints 2–3 a yellowish line edged above with red extends up from below the spiracles to the lateral line. Very obscure lines as before, waved, whitish. Thoracic feet black except at joints, abdominal ones all green, the claspers smoky. Spiracles reddish centered. Later there is a broken obscure substigmatal line, composed of oblique, pulverulent, yellowish

dashes; the stigmatal line forms undulations over the spiracles and the addorsal line becomes broad, white, sometimes with a median red mark on joint 13.

Fourth stage. — The larva rests on the petiole of a leaf and eats all but the midrib on which it rests. When the leaf is consumed, the stem is bitten off. Head light green, not shining; behind the black ocelli a dark reddish band extends to middle of side posteriorly, ending in a blackish shade and continuous with an oblique line on the body which extends over the spiracle on joint 2 and ends on joint 3 at the lateral line; palpi reddish; width 2.5 mm. Body smooth, green, with a broad, geminate, white dorsal band (addorsal lines), filled in with dull red in some specimens; a narrow waved subdorsal line; a row of white dots in place of the lateral line and a few yellow dots for the stigmatal line. Spiracles light reddish. The oblique line on joints 2–3 is yellow below and smoky red above and may be faintly repeated on joint 4. Setae minute, dark. Feet green, the thoracic ones marked with black on the joints.

Fifth stage. — Head rounded, broad, flattened before; light green; a white line on each side of clypeus and another from palpi converging slightly to vertex of each lobe; lateral band smoky purplish red, fading to yellowish on its lower side, continuous with the line on joints 2–3. Body soft, yellowish leaf-green, tapering posteriorly, full, plump, cylindrical. A broad, yellowish white geminate dorsal band, the space filled in with reddish on joint 13; faint traces of a broken subdorsal and two or three round yellow dots laterally and superstigmatally. Dorsum faintly white shaded; subventral region clear, soft green. Thoracic feet reddish, black at tip. Setae extremely minute except on the legs. Claspers brownish. Length about 30 mm.

The species is double brooded at Plattsburgh, N. Y., single brooded in the Adirondacks, though a single ♂ emerged the same season.

Synopsis of the Larvae of Lophodonta.

Smooth green Notodontians, all the feet used, the head held out flat; resting on a perch when young.
- A continuous red stigmatal line the whole length . . . *angulosa.*
- A stigmatal red line on joints 2–3 only, turned up at the end . . . . *ferruginea.*

SCHIZURA NITIDA Packard (= *badia* Pack.).

Received from Mr. Jacob Doll from the vicinity of New York City.

Egg. — More than hemispherical, flat on the base, covered with shallow, rounded hexagonal areas, not distinctly defined and becoming obscure and

punctiform around the micropyle. Diameter 0.8 mm., height 0.6 mm. Laid 3 or 4 together on the under side of a leaf of the food plant (*Viburnum*).

First larval stage. — On joint 2. two subdorsal setae on enlarged bases; on joint 5 a single dorsal hump bears tubercle 1; on joints 6–11 two humps, tubercle 1 on each, becoming smaller posteriorly; on joint 12 a low single hump. Head higher than wide, the lobes distinct; pale testaceous-brown. Body shining red-brown finely mottled with yellow, this color replaced by clear yellow subdorsally on joints 3. 4, 6. 8. and 11, and subventrally on joints 6, 8. and 9; feet dark. The setae have rather large, slightly conical, brown, chitinous tubercles, normal in arrangement (6 absent) with several on the lower part of the square brown leg plate; setae slightly enlarged at tip. Anal feet elevated.

Second stage. — Head bilobed with a tubercle at the apex of each lobe; red-brown with a rounded, pale yellow patch on each side of clypeus above, one on the side of each lobe and the clypeus itself the same color; ocelli dark; a few setae; width 0.7 mm. A red-brown dorsal line with markings of the same color, finely yellow dotted, along the lateral area and covering the whole of joints 5. 7. 10. and 12; the rest of the body pale yellowish, especially on joint 8. The abdominal feet on joints 8 and 9 and the thoracic feet are pale. Tubercles 1 with enlarged bases, forming slight dorsal prominences on joints 2. 5. and 12. Anal feet brown, elevated. Setae dusky with glandular tips. normal, 6 present with 5 or 6 setae on leg plate.

Third stage. — Head small in proportion to the body, bilobed with a large tubercle at apex of each lobe, rather flat before with several setae; pale brownish white. shaded with brown posteriorly with a vertical brown band before ocelli extending to vertex of each lobe, the pair connected by an angular cross band above clypeus and again, faintly, near the vertex; clypeus greenish, ocelli dark; width 0.95 mm. Tubercles 1 with enlarged bases; a slight hump on joints 5 and 12 bearing 1 near the apex; a pair of tubercles in place of the cervical shield. Body at first yellowish except the sides of joints 2–4 which are green. Later shining leaf-green; a purple-brown dorsal band dotted with white extends from joint 2 to the anal feet, widening a little on the middle of each segment, covering tubercle 1 on joint 5, but on joint 6, 1 is bright yellow; the brown color covers the whole of joint 7, even the foot, and stains the posterior half of joint 6 and a stigmatal patch on joint 5. Tubercle 1 on joint 8 yellow. The brown band covers 2 on joints 9 and 10 and stains the foot on joint 10, extending up anteriorly and also posteriorly on joint 11; it covers tubercle 1 only on joints 11 and 12 and becoming very narrow on joint 13 passes to the anal feet. A faint white subdorsal band, stained with yellow, most distinct on joints 8 and 9 and forming a somewhat oblique yellowish mark on joint 11, suggesting the usual V-mark of Schizura larvae. The green ground is partly replaced subventrally by whitish streaks. Thoracic feet pale. Setae pale with glandular tips.

Fourth stage. — Head much as before, but a brown line extending up from the ocelli is all that is left of the brown on the sides of the lobes, and the band connecting the vertical lines above is broken. Width 1.5 mm. Body

as before in color, but the setae stiff, distinct, not glandular. The green of the sides is considerably broken up by whitish streaks; tubercles 1 on joint 6, and 1 and 2 on joint 8, are yellow. As the stage advances, the brown dorsal band partially fades out, the white subdorsal line, broken on joint 11, becomes more distinct, and its posterior part forms a distinct V-mark on joint 11. Tubercles 1 on joints 5 and 12 make slight, but distinct, furcate processes. These disappear in the next stage.

Fifth stage. — Head small, flat before, rounded, higher than wide; white with a faint yellowish tinge; from each side of base of clypeus a band extends to vertex of each lobe, cut by a small spot of the ground color each side of the clypeus and a larger one opposite apex of clypeus and narrowly bordering clypeus above; this band is purple-brown, mottled with round dots of the ground color; a similar fainter band behind the ocelli. A very slight prominence on joints 5 and 12, low, scarcely even a hump; otherwise the body is smooth, tubercles absent, setae small, dark, but tubercle 6 and those on the leg can be distinguished; anal feet elevated. Body green, clear on the sides of joints 2–4 with a dorsal purple-brown band mottled with white, which tapers and ends at joint 5. A white subdorsal shade on joints 5–13, diffuse downward and cut by oblique lines of the ground color (green), broken on joint 11, the posterior part continued forward from joint 11 on joint 10 and becoming yellow, forms a V-mark supplemented by a few dots on joints 9 and 11. A distinct yellow patch surrounds tubercle 1 on joints 6–8 with a yellow dotted dorsal shading; the spots 1 on joint 8 separated by a Y-shaped brown mark (in some cases, the sides of joints 5–8 are more or less covered with dark brown, mottled with whitish, being remains of the brown marks of the previous stage), and the brown usually prevails in a band from the spiracle on joint 5 back to the abdominal feet. Bases of the feet around tubercle 6 waxy white, this area bordered by a rather irregular brown mark. Anal plate and feet dark. Spiracles pale brown. Thoracic feet tinged with reddish.

SCHIZURA EXIMIA Grote.

(Early stages not noted. The larva superficially greatly resembles *Schizura leptinoides* and was at first mistaken for it.)

Fourth larval stage. — Head high, slightly bilobed, flat before; sordid whitish with a vertical band on each side composed of brown-black dots confluent in streaks, continuous on its posterior edge but breaking up inwardly, the pair connected across the median suture by three more reddish, but similar bands which are indented on the suture and, joining there, border the clypeus. Markings on side of head also reddish, dotted, confusedly, broadly reticulate. Width 2.3 mm. A long, nutant process on joint 5 preceded by an elevation on joint 4; a slight hump on joint 9 and a little larger one on joint 12, bearing the whitish tubercles 1. Sides of joints 2–4 sordid whitish, confusedly reticulate with bands of reddish dots which become blackish stigmatally and dorsally, forming a narrow stigmatal and

dorsal band. Body pale brown, faintly marked with dots of red-brown or blackish. V-mark distinct, pale yellow, with no enclosed dot. There is a velvety brown-black subdorsal shade, irregularly touching the region of tubercles 1 and 2, beginning in a narrow line on the side of the process on joint 5, becoming more and more pronounced posteriorly till it fills in all the space around the V-mark. Joint 12 is again lighter, the brown shade forming a pair of narrow lines on the anterior side of the hump, but obtaining again on joint 13. Trace of a lateral line, but broken and diffuse. A distinct substigmatal line. Abdominal feet on joints 7–10 pale, marked with reddish mottlings, the claspers vinous. An oblique brown line runs from base of the horn on joint 5 to the anterior side of the foot on joint 7, and another, subventrally, from below the hump on joint 12 to the posterior side of the foot on joint 10 and, continued back subventrally, ends on the anal foot. Setae short, rather dark.

Fifth stage. — Much as before, but the process on joint 4 is pronounced, leaning backward to touch the horn on joint 5; width of head 3.5 mm. There is a trace of a hump only on joint 8. (Fig. 1.) V-mark distinct, *pinkish*, with centering red lines, but remaining narrow, not diffuse. Dorsal

FIG. 1. *Schizura eximia.* Larva in fifth stage in position of feeding.

shade mossy olivaceous-brown, distinct only on joints 9–13, often quite greenish on joints 10 and 11; joints 6–8 suffused with pinkish dorsally. The area on the sides of joints 2–4 and the bases of the feet on joints 7–10 below the substigmatal line, translucent whitish with sparse dotted brown reticulations. Horn 6 mm. long, tapering, the distal half slender. When full grown the larva becomes paler throughout, though different individuals vary in shade. Feeds solitary on the edge of a leaf.

Food plants. — White birch (*Betula papyrifera*), maple (*Acer*), beech (*Fagus ferruginea*); a larva was found on the ground under an elm tree.

Synopsis of the Larvae of Schizura.

[Note. — The larvae of *S. perangulata* (which may be only a race of *S. eximia*) and of *S. apicalis* are unknown.]

Humped Notodontians with processes on joints 5 and 12, sometimes also on 8 and 9, the one on joint 5 often furcate and nutant; anal feet uplifted. Rest on the edges of leaves and resemble the foliage except in one instance.[1]

Processes on joints 5 and 12 reduced, rounded.

Conspicuously marked, brownish, with hump on joint 5 and head red; tubercles produced, black: larvae gregarious . . . . *concinna.*

Largely green, resembling the green foliage; tubercles obscure: larvae solitary . . . . *nitida.*

Processes on joints 5 and 12 well developed, that on 5 with furcate tip: larvae solitary, resembling withered or distorted leaves.

Sides of thorax marked with green; V-mark conspicuous.

A large white dorsal patch on joints 5–8 *ipomoeae.*

Without white patch . . . *unicornis.*

Sides of thorax not green; V-mark pinkish, tending to become obscure.

Process on joint 5 moderate; a broad dorsal band on thorax and a distinct lateral line on body . . . . . . *leptinoides.*

Process on joint 5 long with a supplementary one on joint 4; dorsal band on thorax narrow; lateral line obsolete . . . . . . *eximia.*

Family Thyatiridae.

With the exclusion of Leptina from this group, as pointed out by Prof. J. H. Comstock, the remainder form a small, compact family allied to the Notodontidae, but with affinities also with the Noctuidae. Four genera occur in our fauna, according to Prof. J. B. Smith's catalogue. Of these the larvae of three are known; they are smooth, noctuiform in appearance, unrelated to the genera at the head of the Noctuid series (Bombycoidae) with which they have been associated. The arrangement of the setiferous tubercles has not been described; but I find from an examination of the two species known to me, that

[1] This diagnosis applies equally well to Hyparpax and Ianassa.

they furnish good family characters, paralleled only in two other families (the Drepanidae and Dioptidae). In the Thyatiridae, tubercles 4 and 5 are situated in line on the central segments, and there is a secondary tubercle above the spiracle, associated with tubercle 3. These characters will presumably be found to obtain also in Pseudothyatira and Bombycia which I have not examined.

THYATIRA SCRIPTA Gosse.

Egg.— Laid at the apex of one of the serrations of a black birch leaf on its side, the apex pointing outward. Melon-shaped with 14 ribs, ending irregularly, some reaching the micropyle, others not; cross striae distinct, the cells three times as wide as long, rectangular, the ends just indicating scallops on the ribs. Base quite similar to micropyle. Color yellowish white, shining; size 0.65 x 0.5 mm.

First larval stage.— Head slightly bilobed, nearly black; width 0.3 mm. Body enlarged a little at joints 3 and 12, smooth, transversely creased, uniform brown of a rather dark shade. Feet normal, all used in walking, but the anal pair held up in rest. Feet dark; anal plate small, black. Tubercles 4 and 5 in line (Fig. 2), but on joint 11, tubercle 4 is a little

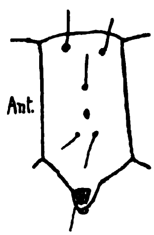


FIG. 2. Tubercles of *Thyatira scripta*, first stage.

higher than 5, and on joint 12 it is remote from it and quite behind the spiracle. The larva sits on the extreme edge of a leaf (like *Notodonta stragula*) or on the back of one.

Second stage.— Sits on the upper side near the edge of a leaf, the head down and thorax contracted, tail elevated; drops off by a thread when disturbed; eats little patches on the upper side of the leaf near the edge. Width of head 0.6 mm. All brown, or greenish, overwashed with brown of an ill-defined shade, marked as in the next stage, but faintly. Tubercles black; setae short. Subventral region vinous-brown.

Third stage.— Position as before, greatly resembling that of *Falcaria bilineata.* Joints 3 and 4 a little folded transversely dorsally, suggesting prominences; joint 12 a little enlarged. Feet normal, the anal pair

elevated. Head bilobed, whitish, mottled with brown dots, especially over the vertex, white around the mouth; ocelli black; width 0.9 mm. Anal plate rather small, triangular. Body smooth except for the small pale setae (Fig. 3), varied with white and brown, sordid whitish on the sides of joints 2–3; subventrally and dorsally on joint 12 brown; a narrow

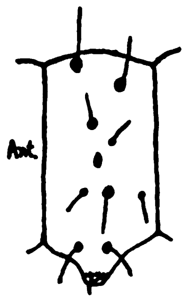


FIG. 3. Tubercles of *Thyatira scripta*, third stage.

straight dorsal and lateral line with pale lateral marks indicating oblique lines. Thoracic feet transparent, abdominal ones pale.

Fourth stage.— Head bilobed, rounded, whitish dotted with brown but leaving a streak of ground color over each lobe, expanding above clypeus; width 1.5 mm. Joint 3 folded to suggest horns, joint 12 a little enlarged dorsally, but all quite smooth; setae fine and pale. Body marked with velvety brown and whitish, the latter in oblique lateral streaks on joints 5–11 and on the subventral fold on joints 5–13, especially on joint 12. A square dorsal area on joints 3–4, light brown; end of joint 13 whitish. A pale shade defines a narrow black dorsal line. Markings all confused, pulverulent. The velvety brown is most distinct in a patch on joints 4, 5, and 12 dorsally. At the end of this stage the larva spins together some leaves, forming a house in which it molts.

Fifth stage.— Lives in a house of leaves spun together. Head roundedly bilobed, pale brownish, thickly dotted with red-brown, the dots segregating into patches and streaks; ocelli black; a few short hairs; width 2.5 mm. Body shaped as before; finely mottled with velvety brown reticulations around dots of yellow and pale brown, predominating laterally so as to form a pale shade which extends on the thorax to the subdorsal prominence on joint 3 and forms a pale, quadrate patch on joints 3–4. Oblique, pale, ill-defined lines on joints 5–12. A narrow black dorsal line. On joint 5, tubercle 3 is black and surrounded by a distinct white patch. Thoracic feet colorless, abdominal ones vinous. Marks more uniform brown, less contrasted than in the previous stage.

Sixth stage.— Essentially as before (see Dr. Thaxter's description of this stage in Papilio, v. 3, p. 10).

Food plants.— Birch (*Betula papyrifera, B. lenta*) and raspberry (*Rubus odoratus*).

Family Drepanidae.

Falcaria bilineata Packard.

Egg.— (See my description in Journ. N. Y. ent. soc., v. 2, p. 108.)

First stage.— Head round, notched from behind at vertex, dark blackish brown; width 0.3 mm. Setae very short, pale with glandular tips; a short thick process on end of anal plate bearing two setae. Tubercles 1 and 2 nearly in line, 3 above the spiracle, 4 below and behind it, 5 anteriorly subventral; a small black leg plate. Body somewhat humpy, the segments obscurely 3-annulate. Color brown, blotched with white, forming distinct patches on joints 5, 8, 9, and 11. Some lateral dots extend the whole length, also on the slight dorsal elevation on joint 12 and on the edge of the anal plate.

Second stage.— Head bilobed, pale brown, dotted with darker brown, with a transverse pale line above the middle; width 0.6 mm. Tubercles pale with enlarged bases, especially the subdorsal pair on joints 3–4; setae short. Joint 13 with a lateral ridge and short upturned process on anal plate. No anal feet. Body varied with brown, white, and yellowish, the pale color predominating on joints 2, 5, 8, 9, and 11.

Third stage. — Essentially as in the next stage. Width of head 1.05 mm.

Fourth stage. — Head as in the next stage, the brown mottlings more confused into blotches; width 1.5 mm. Head bilobed, the apices rounded pointed, distinct. Body roughened by the granular bases of the tubercles; setae short, fine; tubercle 2 enlarged on joints 6, 7, and 12, and especially the subdorsal pair on joints 3 and 4, their bases brown; all the tubercles white. General color rusty brown, shaded with white on joint 5, on 11 laterally, and a luteous white shade dorsally on joints 8–9. Traces of a dorsal line and black shaded dorsal marks especially on joints 6–8 and 10; marks ill-defined.

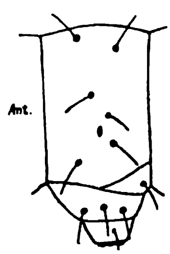


Fig. 4. Tubercles of *Falcaria bilineata.* (The setae on the base of the leg vary from 2 to 4 on different segments.)

Fifth stage. — Head rather square, higher than joint 2, distinctly bilobed, the lobes rounded, flat before; clypeus small. Pale, whitish, thickly mottled with pale reddish brown, the mottlings cut into several areas by narrow lines of the ground color and forming a more distinct blotch below the vertex of

each lobe; ocelli black. Feet normal, the anal ones absent, a short upturned rounded anal process. Tubercles distinct, button-like with short pale setae; tubercle 2 enlarged on all the segments but joint 5; on 3 and 4 the two pairs 1 and 2 each form a partly consolidated process producing a short horn-like structure. A supplementary tubercle below 3 and partly behind the spiracle and other secondary setae subventrally (Fig. 4). Body marked in an undefined manner, varied with vinous-brown and yellowish white; traces of broken dark brown dorsal and subdorsal lines; sides of joint 5 and abdominal feet yellowish white; dark shades predominate on joints 6–7 dorsally. Tubercles 1 on joints 5–12 white, the enlarged ones on thorax and tubercles 2 vinous. The markings just suggest oblique lateral lines. The general appearance varies in different individuals from creamy yellowish with slight marks to dark rusty brown. There is an eversible blackish gland on joint 2 just above the base of the foot.

General Meeting, November 21, 1894.

President W. H. Niles in the chair. Fifty persons present.

Dr. George A. Dorsey gave an account of the Peruvians, prehistoric and modern.

General Meeting, December 5, 1894.

Vice-President Samuel Wells in the chair. Thirty-five persons present.

Mr. Outram Bangs showed a large series of skins of the white-footed mouse, *Sitomys americanus*, and remarked upon the color variation in the various geographical races.

Dr. Charles B. Davenport read a paper on bibliographical reform.

Dr. George H. Parker described the migration of pigment in the compound eyes of Crustaceans and insects.

General Meeting, December 19, 1894.

President W. H. Niles in the chair. Fifty-three persons present.

It was announced that the following Corporate Members had been elected by the Council: Miss Hetty O. Ballard, Miss Mabel D. Clapp, Miss Edith F. Sampson, Messrs. C. R. Eastman, M. L. Fuller, and F. D. Lambert.

The thanks of the Society were voted to Mrs. Asa Gray for her gift of an engraving of the late Professor Gray.

Prof. W. M. Davis read some notes on certain European rivers.

The following papers were read: —

THE GEOGRAPHICAL DISTRIBUTION OF THE EASTERN RACES OF THE COTTON-TAIL (*LEPUS SYLVATICUS* BACH.) WITH A DESCRIPTION OF A NEW SUBSPECIES, AND WITH NOTES ON THE DISTRIBUTION OF THE NORTHERN HARE (*LEPUS AMERICANUS* ERXL.) IN THE EAST.

BY OUTRAM BANGS.

Dr. Bachman in 1837[1] proposed the name *Lepus sylvaticus* for the common cotton-tail or gray rabbit of the United States. He did not describe or name a new animal — it was simply a matter of clearing up the mixed synonomy of the hares and of giving a new name to an old and well-known species. He therefore assigned no type locality for it, other than the United States. The name has since, by the splitting off of subspecies, been restricted to the cotton-tail of the eastern region, extending from northern Florida to the northern limit of the species. This region is, however, occupied by two quite different and easily recognized subspecies, for the northern one of which I propose a new subspecific name, thus restricting the true *Lepus sylvaticus* to the Carolinian life area.

Of all North American mammals the cotton-tail seems to be the most protean, changing, in accordance with the four different faunal areas of the east through which it passes, into

[1] Journ. acad. nat. sci. Phila., ser. 1, v. 7, p. 403.

four well-characterized subspecies. This for a species that hardly reaches the Canadian zone in the north is, I think, remarkable.

The eastern subspecies of *Lepus sylvaticus* may be defined as follows.

Lepus sylvaticus Bach.

Geographical distribution. — Whole of the Carolinian zone from northern Florida to the lower Hudson valley in New York, west at least to West Virginia and Tennessee.

Color (in winter). Upper parts a mixed wood-brown[1] and cinnamon with russet shades, a little lighter on the sides and rump. Upper surface of legs and arms and nuchal patch, cinnamon. Under parts white, pectoral band dull wood-brown. Under fur, including the top of the head, mouse-gray to slate color. Without darker spot or mark between the ears. Ears not very thickly clothed with short hairs — outer margin but little darker. Hair rather short and coarse.[2]

Lepus sylvaticus transitionalis subsp. nov.

Type locality. Liberty Hill, Conn.

Geographical distribution. — The small Transition zone of the east from the east side of the lower Hudson River in New York, extending down the Alleghanies to West Virginia, north to the northern limit of the species in the east, southern Vermont and southern New Hampshire (only in recent years?), and west at the northern part of its range apparently only to the Hudson River.

Color (in winter). Brighter and more intense. Under fur slate color, except on top of the head where it is black. Back and upper parts much darker, owing to the great admixture of long, shining, black-tipped hairs, in some instances about equally black and brown. A conspicuous black spot or mark between the ears. Ears thickly clothed with long hair. A decided black margin on the outer edge of the ear. Hair long, full, and silky. Size of *L. sylvaticus*.

[1] Throughout the colors are according to Ridgway's Nomenclature of colors, Boston, 1886.

[2] Description taken from No. 734 coll. of E. A. and O. Bangs, Raleigh, N. C., Oct. 17, 1893. ♀ adult; total length 427 mm.; tail 55 mm., hind foot 95 mm., ear 63 mm. Collectors H. H. and C. S. Brimley.

Lepus sylvaticus mearnsi Allen.[1]

Type locality. Fort Snelling, Minn.

Geographical distribution. — Upper Mississippi valley south at least to Indiana, probably farther, and east to central New York (Peterboro) and southern Ontario (Toronto). "Iowa, Wisconsin, and Minnesota."

Color (in winter). Lighter especially on the sides and rump, without black mark between the ears. Ears light colored, without distinct black margins. Tail long and bushy. Size large.

Lepus sylvaticus floridanus Allen.[2]

Type locality. Micco, Sebastian River, Brevard Co., Fla.

Geographical distribution. — Southern Florida from Micco south.

Color (in winter). Darker all over, the darkening most intense on the rump; without black mark between ears. Ears sparsely haired and dark, rather darker on outer margin. Size small.

Description of the type of *Lepus sylvaticus transitionalis* Bangs.

Type No. 2407, coll. of E. A. and O. Bangs. ♂ ad. from Liberty Hill, Conn., Nov. 6, 1894. O. Bangs, collector. Total length 431 mm., tail 52.5 mm., hind foot 99 mm., ear 58 mm.

Under fur slate color except on the top of the head, where it is black, showing between the ears a long conspicuous black mark.

Upper parts a russet and wood-brown mixed, shading off on the sides to wood-brown. Upper sides of the legs and arms dull hazel, nuchal patch hazel. Whole upper parts including cheeks, except nuchal patch, and upper surface of legs and arms, thickly mixed with long, shining, black-tipped hairs — giving a variegated look to the whole body — black and brown. Under parts white, pectoral band wood-brown. Ears outside of a shade between wood-brown and russet, bordered on the outer edge with a narrow margin of black, beyond which the long, light hairs of the basal edge of the ear show as a yellowish white fringe. Inside of the ears very sparsely haired. The whole coat is long, full, and silky.

[1] Bull. Amer. mus. nat. hist., v. 6.

[2] Bull. Amer. mus. nat. hist., v. 3.

There are no cranial characters of any importance, except size, by which the skulls of *sylvaticus*, *floridanus*, and *mearnsi* can be separated; *mearnsi* is larger and *floridanus* smaller than *sylvaticus*. There are one or two slight differences, that seem to be fairly constant, by which the skulls of *transitionalis* can be distinguished from those of *sylvaticus*.

The skull of *transitionalis* averages shorter and broader, with the nasal bones shorter and broader than in *sylvaticus*. The postorbital process of the frontal bone also is slender and short, and seldom joins the skull posteriorly, and when it does, only by the extreme tip, always leaving an open foramen between it and the frontal bone.

The postorbital process in *sylvaticus* is broad and heavy and often, in old examples, fused with the frontal bone, with little, sometimes no, open space between.

The incisive foramen is of a slightly different shape. In *sylvaticus* the two outer sides taper to a point just back of the incisors, leaving a cone-shaped opening. In *transitionalis* the two outer sides extend parallel for about two thirds the length of the opening, then suddenly turn in towards each other, making two decided shoulders, and then continue up to the end just back of the incisors, thus leaving a bottle-shaped opening.

MEASUREMENTS OF TEN ADULTS OF *Lepus sylvaticus* BACH.[1]

No.	Sex.	Locality.	Date.	Total length.	Tail.	Hind foot.	Ear from notch
746	♀ ad.	Falling Creek, N. C.	Jan. 10, '94	406	52	84	53.5[2]
741	♀ ad.	" " "	Dec. 27, '93	447	71	102	60
742	♀ ad.	" " "	" " '94	444	62.5	100.5	59.5
891	♀ ad.	Statesville, "	Feb. 22, '94	402	41	86.5	53
736	♀ ad.	Raleigh, "	Aug. 14, '93	402	47	92	62[3]
735	♀ ad.	" "	June 7, '93	440	60	58	60
737	♂ ad.	" "	July 18, '93	419	54	89	60
734	♀ ad.	" "	Oct. 17, '93	427	58	95	63
18	♂ ad.	" "	Dec. 31, '92	425	48	92	65
2	♂ ad.	Washington, D. C.	Feb. 13, '93	453	63	89.5	62[2]

[1] Collection of E. A. and O. Bangs.

[2] Measured by O. Bangs.

[3] Measured by H. H. and C. S. Brimley.

MEASUREMENTS OF TEN ADULTS OF *Lepus sylvaticus transitionalis* BANGS.[1]

No.	Sex.	Locality.	Date.	Total length.	Tail.	Hind foot.	Ear from notch.
2407[2]	♀ ad.	Liberty Hill, Conn.	Nov. 6, '94	431	52.5	99	58[3]
2409	♂ ad.	" " "	Nov. 29, "	429	57	102	59
2410	♂ ad.	" " "	Nov. 29, "	437	55	98	60.5
2408	♂ ad.	" " "	Nov. 6, "	410	68.5	95	58
1207	♀ ad.	" " "	Apr. 19, "	433	52	99	56
1800	♂ ad.	Wayland, Mass.	Oct. 19, "	412	56	95.5	56
739	♀ ad.	Wareham, "	July 26, "	418	45	99	58.5
2406	♀ ad.	" "	Nov. 7, "	408	56	92	58
11	♂ ad.	Princeton, "	Mar. 5, "	408	63	101	53
1799	♂ ad.	Plympton, "	Oct. 16, "	414	64	93	57

MEASUREMENTS OF TEN ADULTS OF *Lepus sylvaticus mearnsi* ALLEN.

No.	Sex.	Locality.	Date.	Total length.	Tail.	Hind foot.	Ear.
2423[4]	♂	Fort Snelling, Minn.	Mar. 23, '89	485	64	107	—[6]
2424	♀	" " "	Apr. 5, '89	445	53	104	—
3488	♀	" " "	" 11, '90	465	60	96	—
3489	♀	" " "	" 10, '90	470	60	100	70
3494	♂	" " "	Nov. 11, '90	446	65	100	70
3501	♂	" " "	May 14, '90	—	62	102	68
3490	♀	Camp Douglas, Wis.	Aug. 29, '90	460	62	110	74
3491	♀	" " "	Sept. 3, '90	475	75	109	72
3492	♀	" " "	" 7, '90	485	75	100	70
889[5]	♂	Elkhart, Ind.	Jan. 28, '94	449	50.5	104.5	58[7]

The measurements of the type of *floridanus* are: "Length 460, tail to end of hairs 65"; but there must be a mistake about the length, as 460 mm. is a greater length than any cotton-tail I ever measured except *mearnsi*, and *floridanus* is evidently a smaller animal than either *sylvaticus* or *transitionalis*. A topotype in the collection of E. A. and O. Bangs, No. 743, is unmeasured but agrees in every way with the type. These two

[1] Collection of E. A. and O. Bangs.
[2] Type.
[3] Measured by O. Bangs.
[4] Coll. Amer. mus. nat. hist.
[5] Coll. E. A. and O. Bangs.
[6] Measured by Dr. E. A. Mearns; ear measured from crown.
[7] Measured by O. Bangs; ear measured from notch.

and a less than half-grown young topotype are at present all the specimens of *floridanus* I know of. The young one, No. $\frac{8011}{1156}$, coll. of American museum of natural history, is exactly like the adults in its color, and very much darker than the young of the same age from North Carolina with which I have compared it.

Intermediates between these races can be found at just the points they would naturally be· looked for. A cotton-tail, No. $\frac{7872}{6225}$, coll. Amer. mus. of nat. hist., from Enterprise, Fla., comes very near typical *floridanus*, but is a little lighter, though darker than specimens from Citronelle, Fla. A series of seven specimens from Citronelle in the collection of E. A. and O. Bangs are in their turn slightly darker than *sylvaticus* from North Carolina. Some cotton-tails from Oak Lodge on the east peninsula, just opposite Micco, are light colored and belong to the Carolinian subspecies *sylvaticus*, which probably extends the length of the east peninsula without change.

In Jan. 1894, Mr. Charles Merriam sent me three cotton-tails in the flesh, that he killed on the bank of the Mississippi, at Trenton, Tenn. These rabbits, No. 886, 887, and 888, coll. of E. A. and O. Bangs, are of especial interest as they are perfect intermediates between *sylvaticus* and *mearnsi* both in size and color. The same winter I received in the flesh from Elkhart, Ind., two cotton-tails; they are extreme examples of *mearnsi* in color but are a little smaller than the average from the type locality.

A rabbit No. 2615, collection of the American museum of natural history, from Toronto, Canada, I refer to *mearnsi*. Two cotton-tails just received in the flesh, from my friend, Gerrit S. Miller, Jr., killed at Peterboro, N. Y., are the same as the Toronto one. One, a ♀ ad., Dec. 16, 1894, Peterboro, N. Y., No. 2414, coll. of E. A. and O. Bangs, measures, total length 469, tail 79, hind foot 104.5, ear from notch 66, which is nearly up to the average of typical *mearnsi*.

I am inclined to believe that the cotton-tail was not native either at Toronto, Canada, or Peterboro, N. Y., but that as the country has been cleared and the forest turned into farming land, it has worked in from the southwest around the shores of Lake Erie; not a very great distance from northern Indiana, whence I have true *mearnsi* (the Elkhart specimen referred to

above). The color of all three of these (the two Peterboro and the Toronto specimens) is a trifle darker than typical *mearnsi*. They all have the large, bushy tail so characteristic of *mearnsi*.[1]

The skulls of the two Peterboro examples are true *mearnsi*.[2]

I can find no locality where *Lepus sylvaticus transitionalis* and *L. sylvaticus mearnsi* come together, and I think the Alleghany Mountains rising from the western bank of the Hudson River form an impassable barrier between these two northern forms of *Lepus sylvaticus*. Both, however, pass into true *L. sylvaticus* at the southern part of their respective ranges.

In all the cotton-tails I have examined I find but few intermediates between *sylvaticus* and *transitionalis*. One from Zelienople, Pa., No. 892, Bangs coll., is a perfect intergrade, lacking the black mark between the ears of *transitionalis* but

[1] As this article goes to print I have just received a letter from Mr. Gerrit S. Miller, Jr., of Peterboro, N. Y., which, as it substantiates with facts my conjecture concerning the presence of *Lepus sylvaticus mearnsi* in Central New York, I publish entire.

"PETERBORO, N. Y., Dec. 30, 1894.

"I have been looking up the history of the cotton-tail in this region and have found some facts that you may think worth inserting in your paper.

"My father tells me that when he was in school in New Jersey, back in the fifties, he saw cotton-tails there and noticed that they were different from the rabbit [the northern hare] that he had been used to seeing here. He was much surprised a few years later to find them common about the farm.

"All the hunters here say that the cotton-tails appeared about twenty years ago. Some of the men say they remember when the first ones appeared, and all have 'hearn tell' of the fact.

"My best evidence is from a man named Wilson who came to this part of the country in 1831, and has lived within fifteen miles of Peterboro ever since. He was a hunting companion of my uncle Green Smith, and lived on his place as foreman for ten or fifteen years, so we all know that he is perfectly reliable. Every winter he used to go west to Ohio or Michigan hunting for market. Out there he got well acquainted with cotton-tails, so he knows what he is talking about.

"The first cotton-tail that he ever saw in New York State was in 1870 or 1871 at Geneva, 60 miles west of here. He wrote me in detail the circumstances connected with the killing of this rabbit. He was hunting with my uncle (who then lived in Geneva), and both were greatly surprised at seeing one of these animals so far east. Since then they have increased rapidly.

"As Wilson was living at Oneida at the time when my uncle was at Geneva (Oneida is only ten miles away from Peterboro), his seeing the first cotton-tail at Geneva is certainly evidence that the animal came from the west. There is no question in my mind that the cotton-tails have worked in during the last twenty years. Just why they waited so long I don't see, for the country hereabouts, at least, must have been fit for them long before.

[Signed] GERRIT S. MILLER, JR."

[2] The skulls of *sylvaticus* and *mearnsi*, as stated above, cannot be separated except by size, while the skull of *transitionalis* can readily be distinguished in nearly every instance.

with the black hairs of the back very conspicuous. Its ears are in color about half way between the two forms. The skull of this rabbit is also intermediate between the two, but is nearer *sylvaticus* than *transitionalis*.

Three cotton-tails, Nos. 19, 20, and 747, Bangs coll., from White Sulphur Springs, W. Va., are of interest. They were all three taken in the same patch of woods, by Mr. Thaddeus Surber; two, Nos. 19 and 20, are extreme examples of *transitionalis*, and 747 is a fine *sylvaticus;* undoubtedly here all stages of intergrades occur.

Transitionalis, therefore, does cross the lower Hudson River and extend down the Alleghanies as far, at least, as West Virginia.

Four skins in the Amer. mus. nat. hist., Nos. $\frac{5648}{5728}$, $\frac{5649}{5729}$, 1692, and $\frac{6967}{5573}$, are also worthy of mention. They are all four from southeastern New York, two from Hastings, one from South Nyack, and one from Suffolk Co. (Long Island). All four are intermediates and vary a good deal among themselves, but the general trend is rather towards *sylvaticus* than *transitionalis*.

Lepus sylvaticus, therefore, comes north along the coast almost if not quite to the lower Hudson in New York.

All through Connecticut, Massachusetts, and southern New Hampshire, where I have myself killed a great number of cotton-tails and examined hundreds of others, principally in the flesh, one never finds an approach to *sylvaticus ;* the conspicuous black mark between the ears is always present and so is the darkening of the back, by the copious admixture of long, shining, black-tipped hairs. From the Carolinas on the other hand I have never seen a specimen that showed any approach to these markings and that could not be picked out at a glance.

If the Carolinian form was in any way an intermediate between the northern and the Floridan forms, I should not for an instant think of naming the northern one, but it is not, and strangely enough the two extremes are more nearly alike than either is to the true *sylvaticus ;* but there is no trouble in picking out the four races at sight, and as geographical races go, they are as good as any.

The only ones I am familiar with in life are *sylvaticus* and *transitionalis*. Their surroundings are quite different, and this

may account for their difference in coloration. *L. sylvaticus* lives in the open fields and broom-grass stretches, in the rank growth of weeds along the "creeks," and in the open southern woods, seldom if ever living in the denser parts of woods or swamps. So noticeable is this that in North Carolina, where this rabbit and the swamp rabbit (*Lepus palustris*) occur together, the latter is called "wood rabbit" to distinguish it from the cotton-tail of the fields. *L. sylvaticus transitionalis*, on the other hand, is seldom found in the open fields, but prefers the seclusion of the thickest swamps, green brier patches, scrub oaks, and old overgrown pastures that have come up to sumacs, alders, roses, and various shrubs.

Mr. Wm. Brewster once told me that he was so impressed with the difference in the habits of these two cotton-tails, that when he came home from the south he looked the matter up and found to his astonishment that they were regarded as one species.

The cotton-tail is continually pushing its way farther to the north and replacing the northern hare.

The two species are seldom found together, and as the hare (*Lepus americanus virginianus*) disappears the cotton-tail comes in.[1]

In the autumn of 1893 I spent a few weeks collecting in Hillsboro Co., New Hampshire, and was surprised to find the cotton-tail abundant. I mentioned this to an old hunter and trapper, and he told me that fifteen years before the cotton-tail was unknown in that part of New Hampshire, but that since then it had year by year become more common, and the hare (*Lepus americanus virginianus*) had decreased in about the same proportion.

Mr. A. C. Brooks of Mount Forest, Ontario, wrote me a short time ago, in answer to an inquiry, that a few years ago the

[1] Dr. Bachman noticed this change taking place at Troy, N. Y., and refers to it on page 328, vol. 7, of the Journal of the academy of natural sciences of Philadelphia, 1837, as follows:—

"About 30 years ago it [the cotton-tail] was not known in the neighborhood of Troy, in the State of New York. The Northern hare was then very abundant. The American hare [the cotton-tail] soon after made its appearance in very small numbers, and, in proportion to its increase, the former began to grow more scarce. For a time they continued to be found in the same neighborhood; but whether the two species were not reconciled to each other, or what is more probable, that the Northern hare was more hunted than the other, it has now become comparatively scarce, while the American hare [the cotton-tail] is exceedingly numerous." This cotton-tail is undoubtedly *Lepus sylvaticus transitionalis*.

cotton-tail appeared in that country and had been gradually working north till at the present time it was common forty miles south of Mount Forest. He failed to get any skins for me as he left the country soon after, so I am unable to tell the race, but suppose it to be *Lepus sylvaticus mearnsi.*

I think this march of the cotton-tail to the north is in a great measure due to the change man makes on the face of nature. The great coniferous forests disappear, and their place is taken by a scrubby second growth largely of shrubs and hard wood. The hare goes with the coniferous forest, and the cotton-tail comes with the second growth.

Lepus americanus virginianus is getting to be a rare animal in Massachusetts. I know of only a few places where it still exists. At Princeton in some places the laurel (*Kalmia latifolia*) is for a long distance the principal undergrowth in the woods, and here, among the old twisted and distorted stems and sheltered by the broad evergreen leaves, the timid and retiring hare still finds some protection. A few still remain in some of the swamps near Concord, and a few also in Berkshire Co. There are probably more in the extensive cedar and maple swamps of South Middleboro, Carver, and South Wareham than anywhere else in the State, but everywhere they are relentlessly pursued. The habit of not holing up but of running before the dogs like a fox, and the larger size of the hare, make it much sought after by sportsmen, and a patient and persevering man with good dogs can get every one in time.

In New Hampshire the hare is still common in places, but in many parts of the State it has wholly disappeared.

To the north, however, through Maine and New Brunswick, it is very abundant, and in Nova Scotia it is thicker than I have ever seen the cotton-tail anywhere. Near Digby, N. S., I once knew half a dozen boys to kill over eighty in a day, without dogs, but by still hunting after a light snow; and my friend H. A. P. Smith of Digby killed in the winter of 1893–94 over two hundred in the woods about his house while training some beagle puppies. Here the hare lies principally in the thick second growth spruce and fir, and in the wetter woods where alders are mixed with the spruces. They are never found in

the hard wood, and seldom take to it when run with dogs, but double and circle about in the spruces. The hare in Nova Scotia is the dark-colored northern form, or true *Lepus americanus* Erxl.; in New Brunswick and Maine, an intermediate form; and in New Hampshire and Massachusetts the light-colored southern form *Lepus americanus virginianus* Harlan, that extends from there down the Alleghanies to Virginia and North Carolina.

THE ORIGIN OF THE ARKANSAS NOVACULITES.

BY L. S. GRISWOLD.

A recent careful and considerate paper[1] by Mr. Frank Rutley has brought out various weak points in the theory of formation of the Arkansas novaculites as advocated in the Annual report of the geological survey of Arkansas for 1890, vol. 3. But the theory as a whole is still defended by its author; and it is hoped in the following paper, by a change in the presentation of the facts and by bringing into more prominence certain facts which are rather deeply buried in the "Report," to present the argument more clearly. A special consideration of Mr. Rutley's views will then be given.

Field conditions. We have in western central Arkansas an uplift exposing a series of strata from the Lower Carboniferous to the base of the Silurian, presenting a conformable section but apparently without the Upper Silurian and Devonian. These strata have been cast into a complicated series of folds of the Appalachian type, and as a result of erosion the harder strata present mountain ridges which extend in the zigzag lines characteristic of the Appalachians east of the Mississippi. The area in which the novaculites are exposed extends westward from the city of Little Rock in a belt from twenty to thirty miles wide for about a hundred and twenty-five miles in Arkansas; the folds of the

[1] Quart. journ. geol. soc. Lond., Aug., 1894, v. 50, p. 377–392.

uplift extend three or four hundred miles farther west, but for how much of this distance the novaculites persist is not known. The strong ridgemakers of the belt are three: some massive quartzose sandstones of the Lower Carboniferous formation; some pure siliceous rocks of very much finer grain in massive beds aggregating 500–600 feet, belonging in the upper part of the Lower Silurian and known as novaculites; and below the novaculites another series of massive sandstones. The rocks of the valleys are chiefly shales which give gradations from well-defined argillaceous, ferruginous, and carbonaceous varieties, through more siliceous kinds to very pure siliceous layers. Limestones also occur, dark blue in color, and believed to be generally magnesian though not widely tested.

Restatement of the argument of origin. — It is maintained that the novaculites of Arkansas are simple, fine-grained, siliceous sediments derived mechanically. Thus they are sandstones of extremely fine grain; sandstones rather than quartzites because there is reason to believe that secondary silica cementing the grains is small in quantity. The reason is based first upon the qualities which novaculite has as a whetstone — qualities which necessarily allow particles of whetstone to be rubbed away in order that fresh scratching points may be presented to the tool — and quartzites are too firmly cemented to admit of use as whetstones; and secondly, a thin section of quartzite under the microscope shows the sides of the grains in extremely close contact without interspaces, while in novaculite the individual particles seem less closely united.

The rock is evidently of sedimentary origin since it occurs as a definite member of a sedimentary series which is of continuous and wide extent, and since a microscopic examination shows quartz grains well rounded by mechanical action, of larger size than those of the groundmass of the stone. For these coarser grains the mechanical origin is evident, but one might urge that the fine particles of the groundmass were a direct chemical precipitate from sea water, as there is no essential difference between these particles and those of silica powder produced in the laboratory. Direct chemical precipitation would be a matter of pure hypothesis, whereas the greater part of the fine siliceous ingredient of slates and shales which is also identical with the

fine particles of novaculite can be ascribed to a mechanical origin.[1] Thus the Arkansas novaculite would equal a slate minus the argillaceous component; and impure novaculites are found with slates, as in the Boston Basin where they have been collected by Mr. J. B. Woodworth. In Arkansas the argillaceous rocks of the series are shales, and the series offers all gradations between clayey strata, used in the manufacture of bricks, through siliceous shales to the novaculites. The theory of mechanical origin is therefore preferred to that of direct chemical precipitation.

The pure silica of the novaculites might have been derived from sea water by the agency of certain organic forms, as has been demonstrated for some siliceous strata elsewhere,[2] but a careful search with the microscope has failed to show signs of such organisms in the rock, and it is not probable that the traces of life have been obliterated by metamorphism or dynamic action. The whole series of strata which includes the novaculites has undergone the same strains, yet in the fossil horizons the organic forms are not noticeably distorted; so while there has been an abundance of small movements along joints, there is no reason for believing that such action extended to particle on particle.

Metamorphism of some sort has been the most frequent suggestion for at least a partial explanation of the origin of the novaculites; and if reasons can be given for believing in the absence of much metamorphism it will not be necessary to discuss the various hypotheses in detail. The geological occurrence of

[1] In a paper entitled "Observations upon the erosion in the hydrographic basin of the Arkansas River above Little Rock" (Ann. rept. Ark. geol. surv. for 1891, vol. 2, p. 153-166), Dr. J. C. Branner gives the results of the observations of a year upon the material transported in solution and suspension by the Arkansas River. The coarser solid matter pushed along on the stream bed was not included, so the results have a stronger bearing on the point at issue. It is here stated (p. 162):—"Taking the observations of the entire year under consideration, *the matter in solution is equal to about* .31 *of that in suspension*. . . ." Analyses of filtered river water taken at different stages of volume in the river contained 1.83 and 11.81 per cent of silica. The sediment carried in suspension shows "sand and insoluble matter" 85.18 per cent, "soluble matter" 14.82 per cent. A complete analysis of the sediment collected with six liters of water is silica 69.53, alumina 11.65, iron oxide 4.46, carbonate of lime .6.62, carbonate of magnesium 3.52, potash .66, soda 1.14, organic and volatile matter 2.95, total 100.58. Thus the quantity of silica carried by the Arkansas River in solution is minute as compared with that in mechanical suspension. To generalize upon these facts and say that all slates and shales are made up of mechanical and chemical silica in proportions similar to those of the above river materials would be quite unreasonable, yet the writer feels a strong support in these observations for a belief in preponderating mechanical silica in such rocks.

[2] Ann. rept. geol. surv. Ark. for 1890, v. 3, p. 178-180.

the rock is the strongest argument against metamorphism. A columnar section[1] of the rocks including the novaculites comprises sandstones, limestones, shales, and siliceous shales grading into true novaculites. Beds of all the above rocks at one place or another lie adjacent to siliceous beds sufficiently pure and fine-grained to be called novaculites. The sandstones have been somewhat cemented by secondary silica, but would scarcely be regarded as quartzites. Two localities of limestone are recalled where the rock contained visible crystals of the calcareous material indicating secondary action, elsewhere the rock texture was too fine for determination by the eye. Veins of calcite occurred very commonly along joint planes. The more clayey shales received no investigation which would throw light on the matter of metamorphism; the more argillaceous layers of the siliceous shales[2] examined microscopically showed minute flakes of secondary muscovite. The rocks intimately associated with the novaculites thus evidence a mere beginning of metamorphism, so that it does not seem reasonable to suppose either that the above novaculites have been derived from any one of the other kinds of rock by metamorphism or that in itself it has undergone much change.

A petrographic study of the novaculite disclosed evidence of just about as much secondary change in the rock as one might expect. In all samples were evidences of a disseminated lime carbonate either by rhombs of the carbonate itself, apparently calcite, in specimens from valley bottoms, or by rhombic cavities in the stone from the mountain sides, produced by the solution and removal of the carbonate. A few of the smaller rhombic cavities have been filled by secondary silica; small quartz veins occur; and in those specimens containing more impurities occasional small spherulites of chalcedonic silica were noted. Thus the direct evidence indicates a condition comparable to that of the other members of the series.

It may be urged that the above observations on petrography are prejudiced, that a minimum of alteration has been accepted while there was a possible maximum, and that another observer might elucidate evidences from a study of the rock in question

[1] Ann. rept. geol. surv. Ark. for 1890, v. 3, p. 209.

[2] *Opus cit.*, p. 239, slides 41, 42, 43,

which would outweigh the argument from lithological association. For this reason it is necessary to consider in detail the more important arguments offered by Mr. Rutley.

Consideration of Mr. Rutley's theory. — From a study of specimens of the two rocks of the novaculite series which are used as whetstones, and from a study of the data presented in the "Report," Mr. Rutley is led to advocate that the novaculites are "siliceous replacements of dolomite or of dolomitic limestone-beds."[1] There are two main lines of argument; that the groundmass of silica is chalcedony instead of quartz, and that the rhombohedral cavities indicate a previous greater quantity of a dolomitic carbonate. The observations supporting the first argument are two: first, that Arkansas stone under the microscope looks like flint, and "the structure of Ouachita stone is similar but coarser in texture"; secondly, the specific gravity of novaculite favors the idea of a groundmass of chalcedony rather than of quartz. To support the second argument reason is given for believing that the original carbonate was a dolomite, and second, the outlines of the cavities are such as to induce belief that the carbonate of these cavities represented a mere residue of a greater mass, the replacement by silica being shown by the relation of the grains of silica bordering the cavities to the dolomite formerly occupying them.

A discussion of the resemblance of novaculite to flint requires first an understanding of the term flint. Now the writer felt great difficulty on entering the subject of the fine-grained siliceous rocks on account of the varied use of different terms by many writers. Therefore the writer selected for his own use definitions which seemed best established in literature.[2] Mr. Rutley seems to accept the writer's definition of chert, but apparently favors the idea that the silica of flint may be chalcedonic. By the writer flint was regarded as a siliceous rock containing a considerable proportion of opal silica; as such a definition has good authority and gives a means of distinction from chert the writer adheres to it. Novaculite is without opal silica; the distinction between novaculite and flint was regarded as clear, and as nobody had advocated an origin of novaculite from flint there

[1] *Opus cit.*, p. 386.

[2] *Opus cit.*, p. 178–187.

was no further discussion. If Mr. Rutley now has a rock which is identical chemically and optically with novaculite and which he thinks should be called flint, then our discussion will be of a very different nature. Chert was the rock elaborately discussed in the "Report" because a theory of origin from chert had been advocated; and furthermore, chert being by one of the writer's definitions "a crypto-crystalline siliceous rock formed by chemical action, and containing a large percentage of silica in the chalcedonic form," was regarded as more nearly allied to novaculite than was flint, so that if rejected as a source of novaculite an origin from flint would be rejected by the same arguments.[1]

The writer would not feel justified in making a general statement that the texture of Ouachita stone was coarser than Arkansas stone; for there seems to be a very slight variation in size of grains in both stones, a fact perhaps explainable in part by differences in the thickness of the sections.

The specific gravity of novaculite as determined by Griswold and Rutley respectively is 2.643 and 2.6441, and these figures represent the specific gravity of the silica of the rock, as the groundmass is practically all one thing. Prof. J. D. Dana gives as the range of specific gravity for quartz 2.653 to 2.66 and for chalcedony 2.6 to 2.64; therefore Mr. Rutley concludes that the silica of the novaculites should be regarded as chalcedony rather than quartz. Disregarding the possibility that quartz may range lower than 2.653, let us consider what would be expected if the material is chalcedony. First, we should expect sometimes to find evidence of a fibrous structure, for it is improbable that many sections cut at random should fall squarely across the fibres of a chalcedonic mass. Fibrous spots in the novaculites are very small in size and few in number; they are more abundant when impurities are present. Again, if the silica is chalcedonic we should expect to get evidence from a test of solubility in caustic potash, for as far as the writer is aware chalcedonic silica gives a

[1] Mr. Rutley mentions cherts which give no evidence of soluble silica in caustic potash, but a study of his references (Sci. trans. roy. Dublin soc., vol. 1, new ser.—On the nature and origin of the beds of chert in the upper carboniferous limestone of Ireland. By Prof. Edward Hull, M. A. F. R. S.; and The chemical composition of chert and the chemistry of the process by which it is formed. By Edward T. Hardman, F. C. S.) would indicate that probably no chalcedonic silica was present; consequently the writer cannot accord them weight in the argument.

marked result. As both of these tests fail to denote that novaculite is chalcedony the writer feels that the possibility presented by the comparison of specific gravities must be rejected.

From the occurrence of the rhombohedral cavities in the rocks from Arkansas Mr. Rutley finds much support for his argument. He considers them in the early condition when filled by carbonate as well as in their present condition. The early carbonate he believes to have been a dolomite, because dolomite more commonly takes the rhombohedral form than does calcite. To this idea is opposed the fact that rocks of the series associated with those containing cavities contain crystals which gave a lively effervescence with cold dilute hydrochloric acid and were regarded as calcite.[1] For this reason the calcite idea was the one favored in the "Report," and the word dolomite was introduced merely as precautionary.

The cavities are thought by Mr. Rutley to give further evidence of a dolomitic origin by their departure in minor irregularities from perfect rhombohedral form, the conception being that a dolomitic rock in its last stages of replacement by silica would present scattered patches of dolomite having such an irregular outline. It would seem to the writer that the cavities were too constant in size and form to admit of such an explanation.[2] The point, however, is an important one and cannot be dismissed by a mere statement of opinion, because it is an evidence by which Mr. Rutley infers a former greater quantity of the carbonate. That Mr. Rutley's explanation of the slight irregularity in form of the cavities is the necessary one is not demonstrated; the writer would still claim consideration of his early idea that "some granular silica like that of the groundmass of the rocks has been either forced into some cavities or deposited there from solution so that the rhombic outline is often obscured.[3]"

Again, the somewhat orderly arrangement of silica grains about the cavities, the longer axes of the grains tending to take a position perpendicular to the side of the cavity, is regarded by Mr. Rutley as evidence that the carbonate existed before the deposition of the silica. If the silica is deposited around the

[1] *Opus cit.*, p. 137.

[2] *Opus cit.*, p. 104.

[3] *Opus cit.*, p. 187.

carbonate and an orderly arrangement is detected, we should expect such arrangement to indicate optical accordance of particles, but Mr. Rutley states[1] that "the optical orientation is not always the same." Furthermore, if such arrangement depended upon the solution of a mass of carbonate we should expect to find it more completely enveloping all the cavities. A re-examination of the rock containing carbonate, having this special point in mind, disclosed no orderly arrangement about the carbonate. Thus it would seem that the feature so commonly observed in the Ouachita stones depended not upon the replacement of the carbonate, but upon the leaching of the carbonate of the cavities themselves, and consisted of a slight cementation of the grains bordering on the carbonate.

Summary of the arguments. The writer does not consider that identity of novaculite with a chalcedonic flint is at all established by Mr. Rutley, and the specific gravity argument is rejected, so that he would still hold to a quartz composition for the rock. Then it would seem just as probable that the original carbonate was calcite as that it was dolomite; also the idea that there has not been more carbonate than is evidenced by the cavities seems as strong as the opposed one. If a decision concerning the origin of the Arkansas novaculites rested upon the points last discussed, it would be an unsatisfactory one. The argument from field conditions seems much more definite; the fact that various kinds of shales grade into novaculites with sandstones present in the columnar section favors the idea of mechanical sedimentation, while the occurrence of dolomitic strata unchanged to novaculites is strongly opposed to the replacement theory.

General Meeting, January 2, 1895.

President W. H. Niles in the chair. Thirty persons present.

The following paper was read: —

[1] *Opus cit.*, p. 386.

THE TUSAYAN NEW FIRE CEREMONY.[1]

BY J. WALTER FEWKES.

The discovery of the use of fire was one of the most ancient in the history of human culture. It occurred far back in the evolution of man and was certainly not only one of the first, but also one of the greatest in the long line of discoveries, which distinguish man from the brutes. No savage race ignorant of the use of fire survives, and archaeology affords no evidence or at least no knowledge of man without it. We have in fact no means of knowing anything of a human society ignorant of this mother of all arts, but we may reasonably conclude that it could not have been much higher than that existing among anthropomorphoid animals.

Almost all races refer the discovery of fire to their mythic history, and most of them have deified the discoverer. This discovery made such a profound impression upon the human mind that it has been given a unique place in most rituals, and is one of the few human discoveries which have been so treated. The antiquity of the new fire ceremony is so great that it is evident in studying this rite we are dealing with one of the most ancient components of rituals. It is an element of culture which has a genetic connection with ceremonials dating back to the dawn of human history. While the widespread existence[2] of the new fire ceremonials among people of every race affords evidence of its antiquity, our knowledge of its modifications, where it survives, is not all that could be desired, certainly not all that is possible to obtain. Science may yet gather up many clews which may lead by comparative methods of treatment to an idea of the ancestral ceremony, but before it is possible to generalize we

[1] This article is one of a series devoted to the ritual of the Tusayan Indians. Many of the observations were made by the late Mr. A. M. Stephen who at the time of his death at Keam's Cañon, in the spring of 1894, was attached to the Hemenway Expedition. It was my intention to delay publication of my notes on the New Fire Ceremony until a final memoir could be prepared, after new studies of this observance. As it was impossible to take up again the field work on account of other duties, I have written out my notes, and the observations made by Mr. Stephen, as a preliminary account of this interesting rite.

[2] The miraculous lighting of the new fire at the holy sepulture is so well known that it need only be mentioned to call attention to the survival of new fire ceremonials in Christianity.

ought to have more exact observations of the details of the new fire ceremony wherever it survives, especially in less modified, savage, or primitive peoples. In the present article I have attempted to give an outline of the new fire ceremony as it exists among the Pueblo Indians of Tusayan.[1]

The current legends of the way the new fire was first obtained by man are numerous, but as they afford small help in the study of the ritual I have paid little attention to them in this article. In certain pueblos, not of Tusayan stock, there is reported to be a fire society, which may correspond to one or the other of those that participate in the events which are described in the following pages, but I have purposely avoided obvious comparisons with them from various reasons, one of which is that it would increase this account to undue proportions. Moreover the ceremonies here described are not the sole fire rites[2] existing among the Tusayan Indians, although so far as I know they are the only ones where the new fire is kindled with a great ceremonial.

The celebration of the new fire ceremony among these people possesses elements of dramatization. Originating possibly as a practical means of furnishing fire to every household, the time of its celebration has long since, in Tusayan, ceased to be the only one in the year when fire is lighted, although still kept up as an important part of the ritual.

It would seem from a study of the events accompanying this rite that the element of phallic worship in it plays a not inconspicuous part. This may be seen in the phallic emblems and decorations,[3] and is suggested by the bawdy jests indulged in by the participants.

[1] In an ethnological study of the evolution of the new fire ceremony, and the status which it has come to occupy in ceremoniology, it is first necessary to collect a body of facts for generalizations; but little progress can be made until the body of facts available is large. Very naturally the study of ceremoniology is now in the ascendant, offering a larger insight into the question of the origin and evolution of human culture than can be appreciated.

[2] The *Sumykoli*, a strange personification, in olden times performed a fire dance which is spoken of by the present priests of Tusayan as far superior to any of those practiced by the nomadic tribes.

[3] While several ethnologists speak of phallic rites among North American aborigines, others stoutly deny their existence. The facts recorded in the present article lead to the belief that this worship probably existed in former times and still survives among the Tusayan Indians. I have in my collection of dolls one representing *Kokopeli*, a personage who there is cause to believe is of phallic nature.

It is interesting that the initiation of youths into the priesthood is likewise so intimately associated with the new fire ceremonials. This as well as the phallic rites suggests the infancy of man of other races where there is a like association with new fire observances.

The celebration of the new fire rites was naturally an appropriate time for sacrifices to the Fire God, and for offerings at the shrine of his hideous and much feared complemental female personage, *Tüwapoñtumsi*. The reason for the association of the Dawn Woman (*Talatumsi*)[1] with the new fire observance is not so evident, but the connection must be an important one from the fact that in the elaborate observance, of which the present ceremony is an abbreviated form, her effigy was brought into the pueblo (Walpi), and on consecutive days placed in succession on the hatches of the four kivas.[2]

While from the character of the celebration, as well as its most striking events, we can readily divine the general significance of the ceremony, I feel that any explanation given in the following pages is more or less incomplete. From the nature of the prayers and the attributes of the deities addressed, I am led to the belief that it has some relationship with germination. The omnipresent desire for rain has also tinged portions of it, but its close resemblance to one of the women's ceremonials, which seems to be a prayer to the Germ God, for fertility of crops, animals, and human beings, leads me to refer this fire observance to the same category. The germ gods, the earth gods[3] and goddesses play important parts, although it must be confessed the connection does not at first sight appear to be very close.

Prayers were made to certain obscurely known earth goddesses. *Tüwapoñtumsi* in my scheme of classification is placed among

[1] *Tüwa*, sand, earth; *poñya*, altar; *tumsi*, woman. *Tala*, light, day; *tumsi*, woman.

[2] The name *Wüwütcimti* is commonly applied to the celebration of the abbreviated new fire ceremony from the fact that the *Wüwütcimtû* society takes such a prominent part. The fire god is personated by the chief of the *Kwakwantû* (Anawita), and the signal for sacred fire making is given by the chief of the *Tataukyamû*.

A proper understanding of the new fire ceremony implies a study of the *Naacnaiya* (*q. v.*) to which this article is supplementary.

[3] *Masauwûh*, the Fire God, is a Death God, and also a god of the surface of the earth. He is likewise said to be a god of metamorphosis, but his function as such is not so clear to me.

the earth goddesses of whom I recognize the following, some of whom are undoubtedly the same beings under different names, expressing different characteristics.

Kokyanwüqti, Spider woman, sometimes called *mana* (maid).

Hahaiwüqti, Old woman.

Two *Calakomanas*, Corn maids.

Tüwapoñtumsi, Sand (earth) altar woman.

Lakonemana, Maid of *Lalakonti*.[1]

Huzrüwüqti, Woman of hard substances, coral, shell, etc. Associated with the western home of the sun.

Müyiñwûmana, Mother of germs.

The personage, *Talatumsi* (*tala*, light, *tumsi*, woman), would seem to belong to the sky goddesses.

If I am right in my theory that the Tusayan mythology and ritual has grown up by composition, and by incorporation of different cults, we have a ready explanation of the reappearance, under different names, of the same earth goddess. As each people joined the nucleus it brought its peculiar cultus, and we could hardly suppose it would drop its nomenclature of the gods even when the characters of its divinities were practically the same as those already worshipped. Somewhat parallel conditions may be traced in Egyptian mythologies, which were highly instructive in connection with Tusayan myth and ritual.

As we have in the *Wüwütcimti* an abbreviated *Naacnaiya*, there are consequently many similarities between the two performances. In main events and the societies which celebrate them they are identical, but there are many episodes in the elaborate which are absent in the abbreviated presentation. This variation is mainly due to the introduction in the former of the initiation of the novices, but in essentials they are the same, and descriptions of the rites in *Naacnaiya* may be relied upon as true also of the *Wüwütcimti*. This likewise holds true of the dress of participants, and the decoration of their bodies. The patrols and processions of the priesthoods through the villages were identical, so that I have not thought it necessary to repeat my descriptions of these except where there are important

[1] Possibly *Mamzraumana* should likewise be regarded an earth goddess, the same as *Tüwapoñtumsi*. The sand-picture and effigy of the *Lakonemana* may be seen by consulting my account of the *Lalakonti*, *op. cit*. For statuette of *Mamzraumana* see account of *Mamzrauti*.

abbreviations, or when this article supplements that already published.[1]

While there is little doubt from what is recorded in this article and in the published account of *Naacnaiya* that we have a fair sketch of the new fire ceremonials, much additional study is necessary before the complete ceremony and its significance can be made known. One example of the obscurity which hangs about this subject may be mentioned.

The parts of the *Wüwütcimti* most baffling to interpret are those relating to the episodes which it shares with a sister society called the *Mamzrautû*. What is the meaning of these similarities and the relationships implied in the names, brother and sister societies, by which the *Wüwütcimtû* and *Mamzrautû* are designated? It has been suggested that both[2] these societies came from the old pueblo, Awatobi, now in ruins, and the cult was rescued from that place at the time of its overthrow. One or two facts certainly look that way, for the legends declare that both are of foreign origin, and the details of their presentation are strangely unlike the other rites in Walpi. The deeper I study the ritual of the Tusayan Indians the more I am convinced that it is a composite product, so intricate in its relationship to the different families and clans of which the people are composed, that it is well-nigh impossible to trace the different components to their sources.

The following description embodies the result of studies of this ceremony made in two observances, one in the year 1892, and the other in 1893. In both years active ceremonials began on November 13,[3] and continued five days, which with two additional preparatory days have the following nomenclature:—

November 8, *Tcotcoyuñya*, Smoke assembly.
" 9, *Tiyuñava*, Announcement.

[1] The *Naacnaiya:* A Tusayan initiation ceremony. Journ. Amer. folk-lore, v. 7, no. 27.

[2] It would be rather difficult on this hypothesis to explain the existence of these rites in Oraibi.

[3] This is a remarkable fact considering that the Tusayan Indians can neither read nor write, and are ignorant of our almanacs or calendars. Although this is the only instance when the assembly of a society fell on the *same day* in two successive performances (a year apart) of the same ceremony, the variation is never very great, and does credit to the astronomical knowledge of these rude people.

November 13, *Yuñya.*
" 14, *Cückahunü.*
" 15, *Komoktotokya.*
" 16, *Totokya.*
" 17, *Tihüni* or *Pigumnove.*

November 18 was called *Ovekniva* (holiday) as all serious ceremonials had ceased.

Analysis of the Observances on Different Days.

The eight ceremonial days, four of which are without special observances, and do not count in enumerations, and four with continuous active ceremonials, are divided into two groups. The first group includes the following: —

November 8, *Tcotcoyuñya*, Smoke assembly.
" 9, *Tiyuñava*, Official announcement.
" 10–12, No ceremonials observed.

These days form a first group which, in such complete observances as the snake dance, is composed of eight days. The second group also begins with a *yuñya*, assembly day, and has five days, but in both the *yuñya* is not strictly a ceremonial day. The time of announcement is also not regarded as a ceremonial day, so that while the observance occurred on the ninth day before the final public exhibition there are only four which count as active days.[1]

November 13 (first day[2]). — Charm liquid altar (*nakü̈yipoñya*) made in all the kivas. Invocation to the six world quarter divinities (*nananivotuñwainita*). Sacrificial offerings and *paho* manufactured. Ceremonial fire making in the Moñkiva. Sacrifices to the Fire God. Processional visit to the shrine of *Tüwapoñtumsi* and site of Old Walpi. Shouting under the cliffs.

November 14 (second day). — Processions and patrols of the societies through the pueblo throughout the day.

[1] The ceremonial paraphernalia remained in the Kwankiva until the 20th although the medicine bowls and fetishes were taken from the other kivas on the fifth day (November 17). This would seem to indicate that traces of eight active days of the second group can still be detected although the whole ceremony is abbreviated from sixteen to eight days, counting both groups.

[2] First day of active participation in the second group of days.

November 15 (third day).—Processions and eccentric dances at intervals, with phallic survivals and drenching of the celebrants with water and other liquids.

November 16 (fourth day).—Invocation to the world quarter divinities. Sand altar made in Alkiva. Midnight songs. Processionals and dances, with accompanying drenching of the participants by the women spectators.

November 17 (fifth day).—Processions, dances, and phallic rites. Offerings at Tawapa, the shrine of *Talatumsi*, and the sun shrine. Purification (*Navotciwa*), and casting the embers of the new fire over the cliffs, with accompanying invocations.

The *Wüwütcimti*, as the *Naacnaiya*[1] ceremony of new fire, was performed by four societies: the *Wüwütcimtû*, *Kwakwantû*, *Tataukyamû*, and *Aaltû*. The *Naacnaiya* does not occur every year, but when it does occur it seems to exert a profound influence on several other ceremonials. The *Lalakoñti*, *Mamzrauti*, *Nimankatcina*, snake dance, flute ceremony are always nine days long or close on the sixteenth day after official announcement, but on the years when the *Wüwütcimti* occurs abbreviations may be expected in *Soyaluña*, *Powamû*, and *Palülükoñti*.

Some facts in regard to the origin of the sacred paraphernalia are instructive. The fetishes of the *Wüwütcimtû* were brought to Walpi, it is said, by the Squash people, now extinct. Sûñoitiwa, the chief of this society, belongs to the Asa people, but his father was the last of the Squash, and on his death, as there were no women left of this family, he obtained the chieftaincy in an irregular manner.

The *Pieb* or Tobacco family are said to have brought the fetishes of the *Tataukyamû* to Walpi, and the *Honauûh* (Bear) and *Pakab* (Reed) peoples each brought a set of fetishes of the *Aaltû*, consequently there are to-day two chiefs, each with his own *tiponi*, in this organization. The *Patki* (Water house) people, the legend runs, introduced the fetishes of the *Kwakwantû*.

[1] An exhaustive study of the *Naacnaiya* is yet to be made, and one must observe due caution in generalizations based on the incomplete observations which have thus far been published. It is also desirable that the new fire ceremonials at Zuñi should be described for comparative purposes. Nothing of any value has yet been published on this interesting rite in any but the Tusayan pueblos.

Of the above mentioned societies, the *Aaltû* and *Kwakwantû*, are brothers of the sister society, the *Lalakoñti*, and the *Wûwûtcimtû* and *Tataukyamû* are brothers of the *Mamzrautû*.[1]

Tcotcoyuñya, Smoke Assembly.

The opening event of the new fire ceremonies took place five days before their formal assembly, and was called the smoke assembly. This smoke talk occurred on November 8, 1893, at about new moon.

The following persons were present at this gathering: —

Hani, *Tataukyamû ; moñwi*, chief.

Tuwasmi, Winuta, } *Aaltû ; moñmowitû* (pl. *moñwi*).

Sûñoitiwa, *Wûwûtcimtû ; moñwi*.

Anawita, *Kwakwantû; moñwi*.

The smoke assembly met at the home of the mother of the chief[2] of the *Wûwûtcimtû*, and each of the above mentioned chiefs spun a short cotton string with a feather attached to the end. Hani spun longer strings also with feathers attached to the extremity.

Sûñoitiwa was a most important personage in the *Mamzrauti*, and his part in that kindred rite may be seen in my article upon it (*op. cit.*, p. 223, 237, etc.).

The following list gives the families and totems of the chiefs: —

Hani, Tobacco people ; totem, tobacco plant.

Tuwasmi, Reed people ; totem, reed, *Phragmites communis*.

Winuta, Reed people ; totem, reed, *Phragmites communis*.

Sûñoitiwa, *Tcakwaina* people ; totem, head of *Tcakwaina*.

Anawita, Water house people; totem, rain cloud, and corn plant.

[1] I have in my account of the ruin of Awatobi (Amer. anth., Oct., 1893) indicated that the *Mamzrauti* originally came to Walpi from that place. The *Patuña* (Squash) people are also said to have lived in the same place with the *Tübic* (Sorrow), *Atoko* (Crane), and *Kele* people all of whom are now extinct in Walpi. The *Patuña* brought the fetishes of the *Wüwütcimtü* to Walpi, but there is some doubt to what phratry this people belonged; some say to the Snake, others to an extinct group.

[2] This is a universal custom in the smoke talks when the times of the great ceremonials are agreed upon. The meeting place is at the home of the mother of the most important chief. The exact date is of course determined by observations of the sun on the horizon, as I have elsewhere explained.

This smoke talk, in the unabbreviated ceremonials, snake, flute, etc., is sixteen days before the final exhibition, or rather the announcement on the following morning is sixteen days from the close of the ceremony. In these great nine days' ceremonials the first day is not considered a ceremonial day so that there are but eight active ceremonial days. We have then sixteen days, between the announcement and culmination of an unabbreviated observance, which shows the marked influence of four world quarter worship. In abbreviated rites there are but five days of ceremony, one of which, the first, does not count as a ceremonial day, which leaves the mystic number four. *Wüwütcimti* as an abbreviated rite has four days of active ceremony and one (the first) assembly day. The call for the assembly was eight days before the culmination of the ceremony instead of sixteen as in the elaborate presentation of the same called *Naacnaiya*.

After having ceremonially smoked and prayed they engaged in conversation, at the close of which Hani filled the pipe anew, lit it, and carried it to Hoñyi's mother's house, where Hoñyi was lying down. Hani formally told him to announce publicly on the morrow at daylight that in four days the assembly of the *Wüwütcimti* would take place, and gave him the feathered strings, which Hoñyi took, thanked Hani, and laid down to sleep.

Public Announcement.

At the faintest dawn of sunrise (*kůyañniptü*)[1] on Nov. 9, Honyi went to the small gap (Hücicovi) at the northeast of Walpi, and there laid the long feathered string (*pühtabi*) upon the trail. He then prayed (*homoya*), and cast a pinch of meal to the point on the horizon where the sun rises. He returned to his mother's house, and on entering it cast meal in a sinistral circuit to each of the world quarters. He so placed six *nakwakwoci* on the floor that they radiated from a common center, one corresponding to

[1] *Talavaiya* or sunrise has the following divisions:—
Talti; first glimpse of light.
Kůyañnüptu; *kutca*, white; *wünüptü*.
Talaove; *tala*, light.
Sikyañnüptü; *sikyan*, yellow.
Tawakülyiva; *tawa*, sun; *külyiva*, appears.
Tawayama; sunrise (sun above the horizon).

each direction. After casting a pinch of prayer meal to each cardinal direction he laid a second feathered string (*pŭhtabi*) near by with feathers extended toward the point of sunrise. Just as the upper rim of the sun peered above the horizon he stood on the house-top, and shouted the following announcement[1] : —

"All people awake, open your eyes, arise.

Become *Talahoya* (child of light), vigorous, active, sprightly.

Hasten, Clouds, from the four world quarters.

Come, Snow, in plenty that water may be abundant when summer comes.

Come, Ice, and cover the fields that after planting they may yield abundantly.

Let all hearts be glad;

The *Wüwütcimtŭ* will assemble in four days.

They will encircle the villages, dancing and singing their lays.

Let the women be ready to pour water upon them

That moisture may come in abundance and all shall rejoice."

On the morning of the fifth day following the announcement the priests gathered in their respective kivas. The day was called the

YUNYA, ASSEMBLY.

November 13 (first day).—Just before sunrise on this day (1893) Hani went into the Moñkiva carrying across his left arm his bundle of fetishes. At about the same time Süñoitiwa retired to the Wikwaliobi, and just at sunrise they set their standards (*natci*) on the kiva hatch. Anawita did the same on the Tcivatokiva which was called the Kwankiva during this ceremony. Neither in 1892 nor in 1893 was any standard erected on the hatch of the Alkiva. The fifth of the Walpi kivas, the Nacabkiva was not occupied throughout the new fire observance.

The gathering places of the four societies were as follows :—

Tataukyamŭ, Moñkiva, chief Hani (Lesma ?).

Wüwütcimtŭ, Wikwaliobikiva, chief Sŭñoitiwa.

Kwakwantŭ, Kwankiva (Tcivatokiva), chief Anawita.

Aaltŭ, Alkiva, chiefs Tŭwasmi, Winuta.

[1] It will be seen from the text that this announcement is not only a call to the society to assemble, but also an invocation to the cloud, snow, and ice gods to bring the moisture. The last lines explain the reason the women pour water on the celebrants.

The ceremonials of a secret nature opened with the manufacture of the medicine, but before we give a detailed account of the way it was made it may be well to consider the extension of a word which has been rather loosely used in descriptions of primitive ceremonial. In the manufacture of the medicine charm an altar was employed.

The word altar is used in my descriptions of the Tusayan ritual in at least two apparently different meanings so that it may be well to clearly define their differences. The one essential object of altars of the first kind, however modified, is the presence of one or more venerated society badges or palladia called the *tiponi*. In the second group this object is commonly missing.

Tiponi Altars.

This kind of altar always has a *tiponi* with varying accessories consisting of meal or sand figures with or without an upright frame or fetishes. The essential object, the *tiponi*, is commonly placed to the west of the *sipapu* or back of the sand mosaic or meal-picture, with fetishes, stone implements, and sacred objects of different kinds varying with the society. The reredos of each society has characteristic symbolic paintings. I have elsewhere figured these accessories of the *Lalakonti*, *Mamzrauti*, Snake, Flute, Antelope, and *Niman Katcina*. This kind of altar is much more complicated than the second kind in which the six radial direction lines are the characteristic. The customary way to place the society palladium (*tiponi*[1]) in position is to draw on the floor of the room six radiating lines of sacred meal corresponding to the six cardinal directions. In the simplest form of the first kind of altar there are no other accessories, simply a *tiponi* placed at the junction of the lines of meal.

[1] The *tiponi* or "mother" is in essentials an ear of corn with accompanying appendages and wrappings. I limit the term as the Hopi do to the society palladium or badge. Every initiated person has an ear of corn which is called the "mother" and is comparable with the *tiponi*, but in the restricted sense in which the word is used by the Tusayan Indians we cannot say that every one has a *tiponi*. While I can readily believe, as stated by Mrs. Stevenson, that "a *yaya* (mother) is presented by the theurgist to each official member" of the society, I am not sure that the form of the *yaya* called by the Sia the lärriko is not limited to the theurgist himself.

Medicine Altars.

In a second kind of altar, which is distinguished from the former by the absence of the *tiponi*, we may have the six direction lines with some other object at their point of junction. Two varieties may be mentioned.

1. Cloud charm altar, in which a *nakwipi* or medicine bowl is placed at the junction.[1]

2. Six directions altar with fire slabs, as described in this article.

In addition to the *tiponi* and cloud charm altars there is another kind readily distinguished from them both. I refer to the simple symbolic figures made in meal used in the Flute, *Lalakoñti*, semi-religious foot races, etc. These are not in one sense altars, but there is an intimate connection between them and the second[2] kind. The character of the sacred rites performed about each of these three kinds of so-called altars varies and determines the nature of the observances.

In an ultimate analysis of secret ceremonials I separate the component rites of each observance into the following divisions or components.

1. Songs, generally sixteen, and attendant rites around or near the *tiponi* altar, invocations to world quarter deities, and consecration of *pahos*. This element I have described in *Lalakoñti*, *Mamzrauti*, Flute, Antelope, etc., etc.

2. Invocation to the six world quarter deities and ceremonial of the six directions (cloud charm) altar. This rite is the making of the *nakü̆yi* or charm liquid and is the invariable and necessary

[1] In this modification of an altar, in which the medicine bowl is set at the intersection of the lines, ears of corn, feathers, stones, aspergills, jaws, skulls, or paws of animals are placed at the opposite end of the meal lines according to the nature of the rite and its significance.

[2] It may be found that the word ara is a better one than altar to designate these sacred places, as the latter implies a sacrifice and was substituted for the former in very early Christian times. The aboriginal term, *poñya*, would be best of all, but as that would convey little meaning to one not acquainted with the Hopi language, I have chosen the nearest equivalent, altar or the Latin *ara*, which are the nearest terms which can be employed. The *poñya* is a place of consecration rather than of sacrifice.

The term reredos hardly expresses the signification of the upright framework back of the sand-picture and *tiponi*, but it is the nearest term which I can find for this accessory of the ara or altar.

component of all great ceremonies. I have described this component in *Lalakoñti*,[1] *Mamzrauti*,[2] Snake,[3] Flute,[4] *Naacnaiya*[5], *Niman katcina*,[6] *Powamû*, and others.[7]

3. Dramatization of myths.
4. Ceremonials connected with initiations.
5. Special ceremonials.
6. Other events which I am not yet able to refer to their proper category. Many of these will doubtless fall into their respective groups as our knowledge widens, and it may be necessary to add new groups to our scheme of classification for their reception. The above is only a tentative effort to simplify the mass of data which has accumulated on the Tusayan ritual, and deals only with parts of the ritual which reappear in each of the great ceremonials.[8]

Cloud Charm Altar.[9]

One of the most important events on the assembly day is the second group, the making of the charm liquid, ordinarily called the "medicine," and the invocation to the gods of the six cardinal world quarters. The character of this ceremony which took place almost simultaneously in the four kivas was shown in my

[1] Amer. anth., April, 1892, p. 117–120.

[2] Amer. anth., July, 1892, p. 221–223.

[3] Journ. Amer. eth. and arch., v. 4, p. 15, 16.

[4] Journ. Amer. folk-lore, Jan., 1895. Journ. Amer. eth. and arch., v. 2, no. 1, p. 123–126.

[5] Journ. Amer. folk-lore, Oct., 1892, p. 191–193.

[6] Journ. Amer. eth. and arch., v. 2, no. 1, p. 73–78.

[7] The deities of the six world quarters more especially addressed in these invocations are the cloud chiefs of these directions, or their servants the six *Palülükoñûh* (plumed snakes), and various other world quarter divinities or peoples. In warrior society celebrations of course the game gods are addressed.

[8] The above classification is provisional and tentative, dealing with broad rather than special observances. Such events as making *paho*, and other prayer objects, sand-pictures, etc., I would refer to group one. Washing of the snakes, kindling new fire, and the like would come under group five. The division of dramatization includes a heterogeneous assembly of the limits of which I am doubtful, but the screen drama of *Palülukonti* and the *Soyaluña* fall in this group.

[9] This altar has been called by several names all of which are synonymous. It is known as the "Six directions altar," the "Medicine altar," and the "Cloud charm altar." I have already described this cloud charm altar in many ceremonials and have given a figure of it in the *Niman katcina* (Journ. Amer. eth. and arch., v. 2, p. 75) and in *Naacnaiya* (*op. cit.*, pl. 2, fig. 12).

account (p. 191, 192, *op. cit.*) of the invocation to the six world quarters, in the *Naacnaiya*. On plate 2, fig. 12, of that article I have given a figure of one of these altars and in the text described the accompanying songs and rites.

The altar was made on a mound of valley sand placed on the floor across which the six direction lines[1] were drawn in meal, and corn was placed at the end of each line as shown in the figure. The medicine bowl was set over the intersection of the meal lines, and prescribed skins were laid near each ear of corn.

The bird skins used in *Wüwütcimti* had a slightly different position from those they occupied in *Naacnaiya*.

Information in regard to the bird skins prescribed for the ends of the meal lines indicating the six directions seems to differ for different societies, although Hani declared that the same kinds ought to be used in all cases.

The following arrangement was used in two societies.

KWAKWANTU.

Directions.		*Bird Skins.*	
N. W.,	Kwiniwi,	Sikyatci,	Tawamana.
S. W.,	Tevyuña,	Lükutckana,	Tcosro.
S. E.,	Tatyûka,	Mûriñyauwû,	Wûrimyauwû.
N. E.,	Hopoko,	Posiwû,	Hotcko.
Above,	Omi,	Tokütcka,	Metcini.
Below,	Atkyami,	Maiyero,	Kwükûpi.

TATAUKYAMU.[2]

N. W.	Sikyatci,	Tawamana.
S. W.	Lükutckana,	Tcosro.
S. E.	Mûriñyauwû,	Wûrimyauwû.
N. E.	Posiwû,	(?)
Above.	Tokütcka,	Aasiya.
Below.	Hotcko,	Tüpûckwa.

[1] N. W., S. W., S. E., N. E., above, and below. The colors corresponding to these world quarters are yellow, green or blue, red, white, black, and all colors. Mr. J. Owen Dorsey (A study of Siouan cults, p. 532) has overlooked the fact which I have repeatedly pointed out that the colors for the above and below, among the Hopi, are black and all colors, exactly opposite of those of the Zuñi. It has also been repeatedly stated by me that the Hopi north is in reality northwest.

[2] This arrangement is almost identical with that of the *Naacnaiya* charm altar (*vide Naacnaiya*, p. 220) and is probably not very far from the prescribed one of all the cloud charm altars.

After the corn and bird skins had been put in position various ingredients were added to the liquid in the *nakwipi* or charm medicine bowl, following the prescribed methods which I have often described. Songs accompanied by a rattle were sung about the bowl, which were preceded and followed by prayers and ceremonial smokes. The events performed in the consecration of charm liquid are abbreviated, but there is a prescribed sequence in arrangement.[1]

The use of feathers in prayers and prayer emblems (*paho*) is a most obscure one and difficult of interpretation. A priest may in a general way be said to barter the *paho* for some benefit he wishes with *Omowûh*, rain gods, who are the chiefs of the six cardinal world quarters (*nananaivo moñmowita*), or with other deities. He places the prescribed feathers on the *paho* because the wise old men said they should, and they not the present priests knew why they used the kinds employed.

As the sun travels across the sky he sees the *paho* in the shrine, but does not take the material sticks, he takes their breath body (*hiksiadta ahpaa*) or *pitcauadta*,[2] their likeness, eidolon. The sun puts them in his girdle and carries them to his western home, and gives them to *Muyinwûh* or some earth deity, who distributes them to the world quarter chiefs. Before dis-

[1] There are unimportant variations in the details of the events accompanying the songs, but the constant features in making charm liquid on a six directions altar appear to be as follows:—

1. Ceremonial smoke.
2. Prayers.
3. Songs, during which we have one or more of the following events:
   a. Placing herbs or charm stones in the liquid.
   b. Sprinkling meal or corn-pollen in the bowl.
   c. Puffing smoke in the charm liquid.
   d. Dipping the six direction corn singly or together in the bowl.
   e. Dipping other objects of the altar.
   f. Asperging.
   g. Throwing a ray of light into the bowl.
   h. Whistling into the liquid.
   i. Raising the bowl and moving it in circuit.
4. Prayers.
5. Ceremonial smoke.

I have not observed dancing about the medicine bowl when the charm liquid is being made in Tusayan.

[2] This term is applied also to a reflection in a mirror or to a photograph. Hence the objection to having photographs taken, as being the eidolon, *pitcauadta*, of the person or thing photographed.

tribution they are sorted; those made by men who are bad or those who are foolish (*kahopi*) are placed one side.

Among the feathers used are those of the following birds.

Sikyatci, yellowbird.

Tawamana, yellow-winged blackbird.

Tcosro, bluebird.

Koyoño, turkey.

Kwahü, eagle.

Kwayo, hawk.

Pawikya, duck.

Moñwü, owl.

The *añwuci*, raven, *wicoko*, vulture, and *kwahü*, eagle, are efficacious in purifications. It is said that the feathers of certain birds are used for game, snow, rain, hot weather, and abundant harvest, and although I have notes on that point the evidences from several sources are too conflicting to be of great value. The question naturally occurs, why use feathers instead of beak or claws, to which the more thoughtful priests reply, because feathers are *koputü*, light, not heavy, and beautiful. Every breath moves them and possibly to the Indian mind they are the nearest approach to his conception of a proper symbol of the "breath body"; moreover they are often beautiful and worthy to adorn the *paho*. If, however, we undertake to explain why the feather has a sacred meaning we cannot limit ourselves to Pueblo Indians, for this conception is as widely spread as the geographical distribution of primitive man. Most of the time passed by the chiefs in the kiva when not engaged in singing or in active ceremonials was devoted each day to the manufacture of *paho(s)*, *nakwakwoci*, and other offerings. The number and disposition of each of these was not sufficiently accurately observed.[1]

[1] This is also true in most ceremonials, and while the manufacture of these objects is not ceremonial it has a more or less sacred significance, and is therefore very properly done in secret. The dance paraphernalia are also repainted in the kiva and the decoration of masks takes place here likewise. The retirement of the kiva, also furnishes a good cool retreat for weaving blankets, and most of these chambers have a log let into the floor with eyelets for the attachment of the lower stick of the primitive loom.

The different kinds of *paho* used by the Tusayan Indians vary in different ceremonials, and are of prescribed size and form. Some are double, others single, and the objects attached to them vary considerably. Some have a facet cut on one of the sticks as shown in a flute *paho* (The flute observance, p. 288), and in others these facets are absent. The *cakwa* or green blue *paho* of the Antelope is accurately figured in my account of the Snake antelope ceremonials (*op. cit.*, p. 27).

Each chief made several cotton strings to the end of which he tied pine needles and certain other prayer offerings which were not noted.

The chief of the *Kwakwantû* (Anawita) made the following prayer emblems.

Four feathered strings for a cloud charm altar.

Six strings with pine[1] needles attached, to be used as sacrifices to *Masauwûh.*

Two *Cakwa* (green) *paho* to be deposited possibly to a female complemental fire goddess.

In singing the songs about the sand altar Anawita beat time with a *keltsakwa* and Masiumtiwa acted as asperger. The chief himself reflected the ray of sunlight into the medicine bowl,[2] as described in my account of the *Niman katcina.* In all essentials there is an exact repetition of this ceremony in all the other kivas, and the details need not be redescribed, as I have already published complete notes in my account of *Naacnaiya.*

New Fire Making in the Monkiva.[3]

This ceremony took place at six P. M., in the presence of all the members of the four societies. The rites opened with the arrival of the other fraternities in the moñkiva where they joined the

[1] These pine needle strings were dropped in the flames after the new fire had been kindled as described in my account of this part of the ceremony. If I am right that Anawita, when he was hidden by the blanket, personified the fire god (*Masauwûh*) it seems very appropriate that he should manufacture the fire god sacrifices. This genial Hopi is chief of the warriors, from which fact he would be naturally the one to represent the war god, *Masauwûh*, but he belongs to the Water house people. The totem of Nasyuñweve who made the offerings to *Masauwûh* in the Antelope snake dance is a picture of *Masauwûh*, but he was not a chief in *Wüwützimti* (see The snake dance, Journ. Amer. eth. and arch., v. 4).

[2] It is of course to be expected that the charm liquid must be made as a preliminary to all religious rites, and on that account this event is generally the very first which takes place. Once made it is not necessary to repeat the rite, and if the supply gives out or runs low there is no objection to adding more to it without special songs. This charm medicine is used not only for asperging but also wherever liquid is needed, as in mixing paint or for other ceremonial purposes. Moreover each society prepared its own charm liquid.

[3] The making of the new fire is described in my article on the *Naacnaiya* (p. 194, 195) and with minor variations, which may be due to errors of observations, the two ceremonials are closely alike. The sacrifices of the pine needles were almost identical in the two, and there was a transmission of the new fire to the other kivas in both these ceremonies.

Tataukyamû already assembled there. The *Wüwützcimtû* came first led by Anawita, who bore in his hand a tray of prayer meal and fire (pine needle), *nakwakwoci*, which he laid on the floor beside that of Hani. After him came Masiumtiwa carrying a stone fire slab and a fire drill. Before each member of the priesthood entered he cast a pinch of sacred meal down the hatchway. The subordinate members passed to the north side of the room and Anawita took a seat on the step in the floor, leaning his back against the north wall. Intiwa and a youth held up before him a black blanket as a screen so that he[1] was hidden from the other persons in the room.

Hayi, who was the last of the *Kwakwantû* to enter, carried a *Moñkohu*, and as he stepped from the last round of the ladder he drew a straight line of sacred meal from the ladder across the spectators' part of the floor to the middle of the east wall of the kiva, and took his position on the northwest side of this line.

The next society to enter was the *Aaltû* led by Winuta also bearing a tray of meal and pine needles attached to strings. He was followed by Tüwasmi with the fire board and drill of that society. The *Aaltû*, with the exception of the two chiefs and Pauwatiwa who were to act as firemakers, passed to the position in the kiva near the fire-place. *Alosaka*,[2] who brought up the rear of this society, stood on the floor of the spectators' part of the room, southeast of the line of meal.

Next entered the members of the *Wüwützcimtû* preceded by their chief and firemakers. After all were seated (squatting posture) the chiefs consulted together with due deliberation. After a solemn stillness Hani, holding his official badge in his hand, slowly rose to his feet.

Then the firemakers in turn fitted their fire drills into the sockets of the fire sticks and made ready for the signal.

The *Kwakwantû* chiefs took the initiative in this preparation, and Masiumtiwa began by spreading a few filaments of cedar bark on the floor before him. He made upon them with corn-

[1] He personified *Masauwûh*, and the act of making fire is called *pilanta* (*pibilauwica*, we make fire). The screening of Anawita was not described in the account of the *Naacnaiya*, probably through an oversight.

[2] The man who personified *Alosaka* wore a helmet or cap with two curved horns. He bore deer antlers in one hand. These *Alosakas* as in other ceremonials are escorts and also watchmen.

pollen six radial lines indicative of the world quarters. Upon these he placed the *pilanowa*[1] in the depression of which he inserted the end of the fire spindle which he held between the palms of both hands.

The *Aaltû* firemaker made a similar set of world quarter direction lines of meal on cedar threads, and upon them he placed cedar bark and his *pilankohu.* He likewise inserted his fire drill in readiness.

The *Wüwütcimtû* firemakers did the same, and all were ready to begin the ceremony, and awaited the signal. The members of the four societies with the exception of the firemakers rose to their feet and Hani said a short prayer. A solemn moment followed at the close of which Hani raised his staff and gave the signal, at which the *Tataukyamû* and the *Wüwütcimtû* broke forth singing different songs. The song of the first society resembled that of the snake priests, at the snake washing.[2]

The *Aaltû* and the *Kwakwantû* did not sing, but at the first note of the other societies the firemakers began to rotate the fire spindles, and soon sparks of fire appeared in the dry cedar timber.

The *Aaltû* firemaker produced fire in a minute, smoke being seen in thirty seconds, but the *Kwakwantû* firemaker with his apparatus, which was stone, was somewhat later, so that almost two minutes elapsed before he produced a spark. No additional material was fed into the fire holes after the rotation of the drill began, but the firemakers relieved each other after intervals of thirty seconds. The songs continued until the fire, now fed with wood, blazed up in the kiva.

Sacrifices to the New Fire.[3]

The fire was then allowed to burn itself down, and Hani with one of the *Kwakwantû* chiefs took up the basket trays containing

[1] Around this stone fire implement was tied a cotton string called the *pilanowa nakwakwoci*, and at the celebration each year an additional feathered string was tied to it, so that there were from fifty to seventy-five of these appendages. The use of a stone fire implement in the Tusayan villages is very old, probably antedating the wooden. Mrs. Stevenson has published a legend of the origin of fire, current at Sia, in which stone fire implements are mentioned.

[2] Journ. Amer. eth. and arch., v. 4.

[3] This "sacrifice" which has been described in the *Naacnaiya* is to *Masauwûh*, and its name freely translated means "the placing of all the chiefs' sacrifices to the fire god" (see *Naacnaiya*, p. 196).

the pine needle strings of their respective societies, and cast them one by one into the smouldering flames. As he made this sacrifice he first brought the string to his mouth, prayed on it, made a pass to each of the six world quarters, and lastly committed it to the fire. Then Sũñoitiwa and Winuta followed Hani's example and made the same sacrifice for their respective societies, the *Wüwütcimtû* and the *Aaltû*. There was perfect silence as this took place, and at the conclusion all resumed their seats. Short prayers were offered by representatives of each society and Anawita from behind the screen responded to all collectively. The import of these prayers was a request for rain[1] and other blessings.

As soon as the fire sacrifice ended *Alosaka* went up the kiva ladder, followed by the chiefs, Hani, Winuta, Sũñoitiwa, and members of the visiting societies. The *Kwakwantû* remained, but after all the others had left the kiva, Intiwa and the lad who held the blanket which concealed Anawita dropped it, and Hayi brushed away the meal line and swept the floor where the societies had stood. The avowed object of this act was to purify the room, for it was believed that this was necessary as direful results would come if the floor was not cleaned.

The procession led by *Alosaka* filed down the trail to the shrine of the dread personage, *Tüwapoñtumsi*,[2] the complemental female of *Masauwûh*, where they made offerings, but would allow no one to see them.[3]

It then proceeded to the site of Old Walpi, and marched in a circuitous route among the huge boulders near that place. *Alosaka* led the procession four times around a space about one hundred feet in diameter which was called the *Sipapûni*.[4] At certain points in this circuit he sprinkled a pinch of meal on the

[1] So constant is this prayer in all ceremonials that it may be said to be universal. To one who has tarried in Tusayan through the dry season this is no cause for wonderment, for their arid environment has profoundly affected the religious ceremonials of the Tusayan villagers.

[2] There are fully as many earth goddesses in the Hopi as in the Aztec pantheon, and it is equally difficult to distinguish their identities. Several of them are but different names or attributes of the same personage. *Tüwapoñtumsi* has certain likenesses to *Lakonemana* (see *Lalakoñti*).

[3] The *Tüwapoñtumsi* effigy is a log of fossil wood in a shrine about 230 feet from the site of Old Walpi, bearing 192° from that point.

[4] The word *Sipapûni* occurred several times in one of the sixteen songs of the Antelopes (see Journ. Amer. eth. and arch., v. 4). The signification of the word has been given elsewhere.

ground, and wherever he did this the chiefs who followed laid upon it a feathered string, and added a little meal (a symbolic prayer), but the subordinate members of the societies simply sprinkled meal at these places. Special *paho* were likewise placed at certain points; the positions being simply depressions in the rocks with no resemblance to shrines.

After having encircled[1] the *Sipapûni* four times the procession in strict silence wound its solemn way up the high bluffs of the mesa to the steep point at the southwest of the pueblo, and while still under the cliff it halted. Then some one said, "Come on, say something,"[2] and one of their number uttered some ribaldic words at which all laughed immoderately, and for a few moments the rocks re-echoed with yells. Immediately afterward the solemn silence was resumed and the procession wound its way up the stone stairway, each society returning to its own kiva. There the members conversed socially for some time and about midnight went to sleep without performing any additional ceremonies on this opening or assembly day.

While the procession was filing down the mesa to the shrine simultaneous events were transpiring in the room where the new fire had been lighted. These were as follows.

After the pine needles attached to strings had been consumed, a young man[3] lit a cedar bark torch from the ember and went to Wikwaliobi kiva, and ignited the fuel which had been gathered in or near the fireplace. He then proceeded to the Alkiva and the Tcivato (Kwan) kiva where he did the same, leaving the remainder of the torch in the fireplace of the latter. He did not visit the Nacab kiva as no society assembled there, and he was careful to see that the fire in the others was well ignited before he left.

In *Naacnaiya*[4] immediately after the firemaking and its transportation to the other kivas Kakapti appeared on the trail with

[1] The circuit was sinistral, or with the center on the left hand.

[2] *Taai lalavai*, come, speak.

[3] In the *Naacnaiya*, Avaiyo, the *Kwakwantû* tyler, carried the fire to the other kivas and he visited the three kivas in the order mentioned. The fate of the cedar bark torch (*kopitcoko*) in the *Naacnaiya* was not observed, but it was probably left in the Kwan kiva. After the purification, when the embers were carried out and thrown over the cliff, the fire was rekindled by a lighted corn cob brought from some neighboring house, and was not made with a match.

[4] *Op. cit.*, p. 196.

the effigy of *Talatumsi*, which was on successive mornings placed on the hatches of the different kivas, as I have elsewhere described.

While the effigy of *Talatumsi* is not brought into the pueblo in the *Wüwütcimti* as in *Naacnaiya*, a special visit to her shrine is made, as elsewhere described in this account.

The procession of the priests to the shrine of *Tüwapoñtumsi* is mentioned on page 197 of my account of the *Naacnaiya*, but it was not then recognized that the shrine (*pahoki*) they visited was that of this personage. Consequently also we missed the visit of this procession to *Sipapüni*, which undoubtedly occurred in the *Naacnaiya*, as described in the present article.

An object of the visit to the *Sipapüni*[1] was for the prayers at that place, and the area encircled is known as *Kütcap tüvela*, the Ash Heap Terrace. It is not far from the site of an old pueblo ruin, and on that account would be especially venerated by the descendants of the former inhabitants. The circuit about this area (*Sipapü*) is called *naluc küniltotim hohomoya*, four times around (?) prayers. The meal and other offerings were made by the societies to the ancestors of the present people of Walpi, and are regarded as efficacious, since the wise old men of the ancient time have "become *Katcinas*."[2] They are appealed to for about all material blessings as well as rain, the constant wish of the Tusayan people.

Among other things prayed for near the site of Old Walpi were:—

Kaü, corn.
Kawaio, water melon.
Melon, musk melon.
Patuña, squash.
Muzribüci, beans.
Pücübi, cotton.
Tüwaktci, sweet corn.
Tüsaka, grasses.
Yoyanwüyü, rain to come.
Kanelo, sheep.
Kawaiyo, horses.

[1] This is the site of an ancient pueblo ruin older possibly than Kisakovi which is more on the point of the terrace. They abandoned this easy site because it was in the shade and too cold, but they say their ancestors were driven from Kisakovi by the Utes, possibly by the fear that the Spanish would return, and moved to the present site of Walpi which was almost impregnable. Some of the middle-aged men remember when the approaches to Walpi on the mesa were by ladders from the terrace, and the former position of those ladders (*Cakavila*) is even now pointed out.

[2] The import of the prayer over a grave when the food is placed there is, "*Umi omau nihte*, you are grown into *Omowuh*."

Pahanhimüyathihta,[1] American, his possessions, all such.

They likewise prayed at this time that the women may be fruitful and the children grow to maturity; that the *Tcübio* (antelope), *Sowiinwa* (deer), *Sowi* (jack rabbit), and *Tabo* (cotton-tail rabbit) may have numerous young.

It is highly probable both from this ceremonial and for other reasons that the Tusayan Indians have a well-developed ancestor worship. The visit to the ancient town is significant in this theory, but shrines or fanes near old ruins are always regarded with much reverence and are used even after the destruction of the neighboring town.[2]

The mirthful episode on the trail after the procession left *Sipapüni* is called *tübisalantota* (sorrow making[3]), and is the same as the jesting sallies of the societies in their procession through the pueblo where the members shout derisive epithets to the women just as the *Mamzrauti* women return the compliment to the *Wüwütcimtü* and *Tataukyamü* as elsewhere described.[4]

CÜCKAHIMÜ.

November 14 (second day).—The ceremonials of this day were very similar to those described in the *Naacnaiya*,[5] and the soci-

[1] The name for American is *Pahano*, from *pa*, water, and *hano*. Hano is probably from the Tewan word, *anope*, east. When the Hopi asked the Asa and Tewa people whence they came, they replied in their tongue, *Anope*, east. Consequently their pueblo on the east mesa is still called Hanoki, eastern house, and the Americans are called *Pahano*, eastern water; (*cinyümü*) all people.

[2] See my account of Awatobi, Amer. anth., Oct., 1893. The shrine of the *Alosaka* at that town was the receptacle of the two effigies up to within ten years, and the shrine near the end of the mesa is still used. With such constancy does primitive man return to ancestral places of worship even after the pueblos near which they are situated have gone down into ruins. This is a common feature in all prehistoric and historic religions.

[3] These abjurations are particularly directed against the women of the *Mamzrauti* society and from their character suggest survivals of phallic practices. See reciprocal ceremonials in *Mamzrauti*. Amer. anth., July, 1892.

[4] The *Mamzrauti*, p. 208, 209.

[5] As it is sometimes stated that the details of the same Tusayan ceremonies vary from year to year and are modified to suit the whim of the priests, I must strongly insist that such statements are entirely erroneous. One might suppose that because the statuette of Dawn Woman was brought into the pueblo in 1891, and not taken from her shrine in 1893, that here we have an important variation in two successive observances of the same ceremonial. Nothing could be farther from the truth. The ritual of *Naacnaiya* prescribes that the effigy of *Talatumsi* should be brought to the kivas, and that of *Wüwütcimti* that she should not. There are variations also in minor details, some of which are probably due to poor work on the part of the describer.

eties made excursions through the pueblos performing their sidelong dances.

The *Kwakwantû* wore the so-called *tokonaka* helmet with a single vertical horn made of a gourd ornamented with raincloud symbols. This head dress is symbolic of *Cotokinuñwa*, "the heart of all the sky," one of the powerful deities in Hopi as in Kiche (see Popol Vuh) mythology. The similarity of the two conceptions is interesting especially as the *Kwakwantû*, who wear the *tokonaka* helmet, are reputed to have come from the far south with the Water house people, to whom their chief, Anawita, belongs.

There are certain characteristics of *Cotokinuñwa* which would imply Christian teaching. His symbol is a cross which alone would not be very important. His home is in the sky, the world quarter in which early Christian missionaries would have placed the home of their God. There is a suggestive poverty of folk tales about *Cotokinuñwa*, and he does not appear in sky deity myths. In the cultus of the dead he as *Tokonaka* is the judge, who throws the erring breath bodies into the four fires, a decidedly Christian conception. To offset all these facts indicating the derivation of *Cotokinuñwa* from Christian teaching is the prominent place which is given to the "Heart of the sky deity" in Popol Vuh, but how shall we know that it was not incorporated from Christian sources in the well-known Kiche sacred book.

Komoktotokya.

November 15 (third day). — The ceremonials of the third day consist almost wholly of processions and patrols about the pueblos, at intervals during the day, beginning shortly before sunrise. The *Wüwütcimtû* society, who made the early morning parade, were led by two *Alosaka* wearing helmets with horns, each carrying an ear of corn in his right, an antler in his left hand.

The character of these processions has already been described in my account of the *Naacnaiya*. The *Wüwütcimtû* in their parades formed two parallel lines, one led by Sûñoitiwa, the other by Suyoko. The members of each line linked fingers and moved with a sidelong motion, the *Alosaka* leading, and the drummer marching between the two lines. Their songs were

very lively, and were accompanied by light taps on the drum. The two lines shuffled along sidewise for a short distance, then returned, and thus back and forth they made their way to the east end of the pueblo, after which countermarching they returned to the west, always preserving the sidewise step, shouting the refrain: —

i-ta-a-mü-ikü-kü-ya-ni

(us) come you water, pour, may.

Come, pour down water upon us.[1]

The song[2] was sometimes interrupted by jibes and indecent gestures, each pointing an ear of corn at the women assembled on the house tops, and they responded in kind, pouring water upon the celebrants, or, descending to the plaza, drenched individual performers or thumped them with their empty gourds.

In certain secular frolics previous to starting out to the fields to plant, the men are sometimes drenched with water in a similar way. "As the water is poured on the men, so may water fall on the planted fields," ever the omnipresent prayer that the gods may water the farms and bless the work of the farmers.

This seemed to be a time when license in act and speech was permissible, especially in the ways of older women, and one quiet housewife, ordinarily of modest demeanor and respectable character, indulged in obscene gestures at the men, lifting her gown, and calling out to them in a way which it may not be best to repeat.

There is no mistaking the thin guise of phallic survivals in these and other actions during the new fire ceremonies. As identical practices have been described in the *Naacnaiya*[3] it may be well to notice the same actions in this ceremony.

Let us turn to the proceedings described in the *Mamzrauti*, where a band of women and girls "having thus arrayed themselves, made an entire circuit of the village, imitating the

[1] See account of the Zuñi *Dumechimche* where the clowns are similarly drenched in midsummer *Katcina* dances.

[2] The song which the *Wüwütcimtü* sing to the women is *Haiyaahaiya*, repeated in lusty staccato.

[3] In my account of this ceremony I have pointed out the evidences that it is a rite in which germination and the germ god have prominence, as in the woman's celebration which precedes it. The relationship to the present observance with its phallic survivals strengthens me in my belief that this theory is tenable.

Tataukyamû (in *Naacnaiya*), singing and pointing with the ears of corn in a sarcastic fashion to the men who came to the edge of the home terraces. . . . The men pretended to be angry and poured water on the women, throwing it promiscuously, as a general thing, but in many instances particular young women were singled out, chased, and douched, and thus from house to house the women continued their serenade. About one half the jars emptied upon them contained urine, most of which had been standing long enough to decompose partially, and the stench in the courts was almost overpowering, although a stiff gale was blowing.

"A half dozen of the young women were chased by the men (no woman threw any liquid or took part, except the celebrants), and these were either thrown down, not violently, or laid down, when overtaken, and when as many as a dozen men had surrounded one woman, they rubbed filth in her hair, on her face, over the upper part of her bosom and neck, etc." In connection with these proceedings other events of the *Naacnaiya* (p. 210) may help us to decide whether we have in them survivals of promiscuous intercourse in public, or phallic rites of a modified kind. This latter nasty drama was thus explained. "During the *Mamzrauti* celebration in September, these two *Wüwützcimtû* were specially active in drenching and besmearing the young maids, and these two Horn sentries called themselves the friends of two of the maids who were liberally drenched at that time." I have no doubt that in these episodes of both *Naacnaiya* and *Mamzrauti* we have a modified survival of an old Saturnalia, and the symbol of the vulva still borne in both *Naacnaiya* and *Wüwütcimti* indicates that they were and still are to a measure phallic rites.

According to legendary history the relationship between the *Wüwütcimtû* and *Mamzrautû* are as follows.

These societies claim to have descended from no less a mythological personage than *Taiowa*, a sun deity who met a maid in the underworld and drew her to him by inhalation through a flute. He took her to *Tawaki* (sunhouse), and she bore him many children. To one of his sons he gave the mysteries of the *Wüwütcimtû*, and to one of his daughters those of *Mamzrautû*. These ancestral persons erected their respective altars in the

underworld, some distance apart, facing each other before the flowery mound (Sitcomovi[1]) on which sits *Mũyiñwũh*. The youth called to the girl his sister

i-ci-wai-ya ũ-mi nũkũc ma-na.

My sister you are nasty maid.

She resented this in pretended anger, and after quarrelling for some time in jest they poured water on each other, and "thus we do hoping rain would come."

Totokya, Sleeps.

November 16 (fourth day).—About a half hour before sunrise the *Wũwũtcimtũ* passed through the pueblos, advancing with the sidelong movement. They did not wear ceremonial paraphernalia, but were dressed in the ordinary way. About noon they again came out of the kiva, but this time they were arrayed in gorgeous dress described in my account of the *Naacnaiya*. The *Alosaka* accompanied the procession. The drummer led, and behind him came the man bearing the moisture tablet (*pavaio-kaci*) which is figured in my account of *Naacnaiya*. In his right hand he carried a staff with dependent string and red horse hair. At intervals he shouted :—

i-na mũ-i yok(i) va ni.[2]

My father, you rain fall, make may.

O father (sun) pour water on us.

Fourteen nude *Tataukyamũ* paraded through the pueblo on the same afternoon. They bore on their backs, breasts, upper arms, and thighs figures of *lũwa* (vulva), *katci* (penis), and phallic devices. Sixteen other members of this society likewise paraded, singing, however, different songs. The hair of the members of each group was brought into knots in front above their foreheads, and decorated with corn husks. Each carried an ear

[1] *Atkya sitcomovi: atkya*, below, under world; *si*, flower; *tcomo*, mound; *ovi*, place of; the flower mound of the below. The name of the pueblo, Sitcomovi, I suppose to have a similar derivation, viz., place of the flower mound. There was possibly a mound on its present site where some flower (*si*) grew when it was built.

[2] The termination *ni* has a potential force here as in *yau-kau-ta-ni;* strong, make may; *mũ-i* is the second personal pronoun; *i-na* may be *i*, my, *na-a*, root, father; my father (*Tawa*, the sun). *I-na* sometimes means simply us; and if used in that sense here the sentence would read; us, you, rain cause, may; a free translation would be, cause rain to come by pouring water on us.

of corn in his right hand, and a realistic imitation of a *lüwa*[1] (vulva) in his left. They halted and sang phallic songs, and made obscene gestures. Women came from their houses and poured water, not the cleanest, upon them.

Several of the women at one time captured one of the *Tataukyamû* from the group of dancers, and dragged him to some convenient corner of the court where they pulled down his hair, and tore off his breech cloth. They then douched him with water,[2] and thumped him on the head with their empty water gourds.

The upright frame back of the altar which is used in the *Naacnaiya* (*op. cit.*, p. 202) was not set up in the *Wüwütcimti*, although the two *tiponis* placed in the sand mounds and the *paho* were the same, and the ears of corn laid between them were also present. There were two *tiponi* in the Alkiva and but one in each of the others, for reasons which have been explained.[3]

At about 1 P. M. the *Kwakwantû* finished making their *paho* and numerous *nakwakwoci*. The curious *pütcpaho* or corn *paho* slab (*Naacnaiya*) was also made, and all were deposited in a tray.

THE TIPONI ALTAR.[4]

In the Alkiva the two chiefs made four mounds of sand and meal arranged in a row and a meal painting on the floor before them. The two middle mounds of meal had upon them the two

[1] Some of these objects were made of hemispherical pieces of wood realistically carved, and covered with wool in the appropriate place. Others were rinds of watermelon, with the green outer skin cut through to show the red meat. These effigies were attached to a short stick, and on some of them pubic hairs were fastened.

[2] Attention is called to my description of episodes of the *Naacnaiya* (*op. cit.*, p. 210) where something similar to this took place.

[3] As the *Wüwütcimtû* is an abbreviated ceremony the uprights are not used back of the *tiponi* altar. By a somewhat similar course of reasoning the *tiponi* altar of the winter flute is destitute of the accessories which appear in the summer observance (see The Walpi flute, a study of primitive dramatization, Journ. Amer. folk-lore, Jan., 1895). For emphasis I will repeat that the essential of a *tiponi* altar is the *tiponi*, and the other things, as sand-pictures, uprights, etc., are accessories.

[4] Here we have the altar of the first kind, and there is no doubt that elaborate ceremonials belonging to my first group of component rites were performed about it during which songs were sung, but our description is incomplete as these rites were not seen, although it is known that they were performed. These songs and observances are recommended as a fruitful field for work for those who would complete my account of the new fire observance.

tiponi, behind each of which there was a pile of sand in which were twigs with attached feathers. The two lateral mounds were of sand at the apex of each of which was inserted a *paho*, and behind it twigs with attached feathers. A long string with attached feather was stretched from the base of the right hand *tiponi* across the sand forming the ground of the meal picture, and meal was sprinkled over it and thrown towards the ladder.

Parade of the Tataukyamu.

At 3.10 P. M. the *Tataukyamû*, eighteen in number, issued from their kiva, and joyfully danced through the courts, linking their hands in the peculiar manner elsewhere described. A portion of them were disguised as women, of whom four wore on the head a large, widespreading, wooden tablet, carved to imitate feathers. In the midst of these was a youth decorated as the other *Tataukyamû* but bearing a skin tablet (*pavaiokaci*), with a rattle in his right hand, an ear of corn in his left. These five accompanied by the *Alosaka* danced to the spirited songs of the *Tataukyamû*. After about twenty minutes they returned to their kiva.

This episode is instructive in view of the relationship of the *Mamzrauti* and *Wüwütcimti* ceremonials. In the *Mamzrauti* of 1892 girls bearing the same tablet likewise danced in the court, and in the presentation of this woman's festival described by me (Amer. anth., July, 1892), these girls or *Palahikomana* were not personified, but represented by a symbolic picture[1] on the wooden slab. These dancers do not represent *Katcinas*, but were decorated with the tablets in old times before *Katcina*[2] came to Walpi. While they thus danced, the accompanying chorus was sung to *Müyiñwûh*, asking him to fertilize the earth, and

[1] Called Calako (Saliko) on account of the symbolic markings of the head or tablet of the same. Probably in this ceremony, however, she has another name but both are in reality the same personages so that the name given her was not inaccurate.

[2] From many reasons I am led to suspect that the *Mamzrauti* belongs to the older group of Tusayan ceremonials antedating the *Katcina* cult. There seems good reason to suspect that the latter came originally from a Rio Grande people possibly of Keresan stock.

fructify all vegetation, animals, and women. The maids with the tablets were called *Palahikomana*, and the dance *Paliktibe*.

The young man who wore the moisture or skin framework was also paralleled in *Mamzrauti* by the leader of the women, *Tcatumaka*, described on p. 238 *op. cit.* The skin tablets which both wore were called *Pavaiokaci*, moisture tablets.

The composition of the name *Tcatumaka* shows that the woman personified the mother of the *tcatü*, and the effigies of the mother of *tcatü*[1] or *Tcatuyumatü* are prominent fetishes on the altar (see *Mamzrauti*, pl. 1, figs. 13, 15). This personage is a strange one in the Tusayan pantheon and it looks as if she were a dread deity who afflicts women and must be propitiated. Hence her place on the altar and her importance in the *Mamzrauti* ceremony.

The curious little wood lice *tcatü* are probably the key note of the *Mamzrauti*. They cause the plant upon the roots of which they live to wither and die, and a man not a member of the *Mamzrautü* will not knowingly have anything to do with them. I requested Mr. Stephen to procure some for me for identification, and a quotation from one of his letters shows his experiences: "I got a man, not belonging to the *Mamzrau* to show me an infected plant. I pulled it up, and found a host of them at its roots — he identified them and I bottled a score for you. The next day this man came to me looking most eagerly anxious and asked whether I had sent you the *tcatü*. I replied 'No.' 'O my brother,' he said, 'those I fear were not the true *tcatü*; give them to me that I may return them to their home in the *siwapi*' (*B. graveolens*). So I gave them to him, and he thanked me fervently and showed me the *nakwakwoci* he had prepared, and we returned down to the valley, and he emptied the bottle back on the roots of the plant, cast prayer meal upon them, and prayed that they might not infest him or his family with sores. He had told some of the elders what he had done and they straightway cautioned him to get the animals back from me and return them with prayer."

[1] The *tcatü* are small insects much feared and venerated which infest *Bigelovia graveolens*. They are dreaded by the Indians as their bites, it is thought, lead to many troubles, and Kopeli said that syphilis came from them. I have recorded what has been told me and leave it to the reader to draw his inferences, but it is certainly strange that ceremonials connected with germination and phallic rites give so prominent a place to the mother of *tcatü*, the syphilis insect.

Dance in the Monkiva.

A fragment of a secret ceremonial was observed on the fourth night in this kiva. At 9.30 all the *Tataukyamû* withdrew to the spectators' part of the room and the *Wüwütcimtû* came in, costumed as during the day processions. They were led by a drummer, but the man with a moisture tablet was absent. They arranged themselves in a double crescentic line about the fire-place, Sûñoitiwa standing at the south end of the inner line, and Soyoko at the north end of the outer. After dancing for about ten minutes Sûñoitiwa passed his badge (*keltsakwa*) to his neighbor on the left, and went up the ladder with the remark, *üm-yü-kau-yuñ-i-ni*, may strength be with all assembled.[1] The dance continued, the lines moving sidewise from right to left and back, and the one to whom Sûñoitiwa had passed the badge handed it to his left hand neighbor, and likewise left the room following his chief with the words given above.

This continued until all but six of their number left; these then ceased singing and with the formal greeting to those remaining went up the ladder and passed to the kiva of their society. This was repeated by the *Wüwütcimtû* at midnight, six persons being the last to leave as on the previous occasion.

An hour or thereabout after the departure the simultaneous celebration of the rites about the medicine bowl began in all the kivas. These rites[2] were as follows:—

At about one P. M. the members of the *Aaltû* made a six-directions (cloud charm) altar, in front of the *tiponi* altar and celebrated the invocation to the six cardinal points. At about the same time the *Kwakwantû* chief dropped a handful of meal

[1] Etiquette requires one entering a kiva to say as he places one foot on the floor, while yet the other is on the last rung of the ladder, "*hin-kwai-kwat-ye-si*," to which those within the room respond, "*kwa-kwat-ai*," or the more formal greeting, "*üm-yü-kau-yuñ-i-ni*."

[2] The time for their inception was determined by the position of the Pleiades, and during the songs watchmen or tylers, muffled up in their blankets, sat at the entrances to the kivas. While there was a general likeness in these songs there was much variation in details and the songs were different, those of the *Tataukyamû* being the most weird.

At the close of the songs *Alosaka* brought down two vessels of water and poured a little on every person's head, which made the singers shiver with cold. The night ceremonials of the fourth day were similar in all the kivas, but the details of each have not been worked out carefully enough for publication.

over the *Sipapû* of the Kwankiva and placed his *tiponi* upon it. Each member tied an ear of corn to a string or scrap of calico and slung it over his neck so that it hung on his breast. They decorated their faces with white pigment. Several songs, of which eight were detected, were then sung, and Tcali kept a score of the songs with kernels of corn which he arranged on the floor in rectangles. There was occasional asperging to the world quarters and rapping on the floor. During the songs a tyler sat on the hatch of the kiva, and from time to time the medicine bowl was lifted from its place on the floor. This singing seemed to belong to the second group of component rites, or the preparation of the medicine liquid and six world quarters invocation.

Simultaneously there was likewise singing in the Moñkiva of the same import, solemn hymns with stirring passages.[1]

It seems evident, therefore, that not far from midnight on the fourth day there was a secret ceremonial of the second group in all four kivas occupied during the new fire ceremony.

Attention is called to the importance attached to the culmination of the Pleiades in determining the proper time for the beginning of certain rites, especially the invocation to the six world quarter deities, among the Tusayan Indians. I cannot explain its significance, and why of all stellar objects this minute cluster of stars of a low magnitude is more important than other stellar groups is not clear to me. Its culmination is, however, very often[2] used to determine the proper time to begin a sacred rite by night.

Tihuñe or Pigumnove.

November 17 (fifth day).—On the morning of this day every one in the pueblo, both men and women, washed their

[1] These songs resemble the nocturnal melodies and rites of the second and third days of *Naacnaiya q. v.*

[2] See *Naacnaiya*, p. 199, 206; *Lalakonti*, p. 117; *Mamzrauti*, p. 231.
Mr. R. G. Haliburton has collected many curious facts in relation to the Pleiades and their position in determination of the time for the celebration of primitive rites and ceremonials. Although I do not feel that I have a broad enough knowledge of the subject to discuss his theory, it is certainly a remarkable fact that this constellation plays such a prominent part in Tusayan ceremony, especially in the determination of the time for certain nocturnal rites which occur among these Indians.

heads,[1] and those of their children, and at earliest dawn a small party of *Tataukyamû* left their kiva and scattered meal in broad trails about the courts and on the kiva roofs. No prayers or songs were heard in the kivas, and at the close of the day the chiefs packed up their *tiponi*[2] and carried them home.

At intervals throughout the day, however, the different societies paraded through the streets and courts giving much the same exhibitions and dressed in the same way as on previous days. They sang their songs to the women who, as on previous occasions, poured water over them, and frequent episodes recalling phallic survivals occurred. On this final day of the *Wüwûtcimtû* exhibition, the costumes were if anything more gaudy and the spectators of the public events more numerous.

Deposit of Offerings.

Six young men of the *Aaltû* in couples went in the morning to all the kivas and received feathered string offerings and *paho* which they deposited in the following shrines. One couple went to the fane of *Talatumsi*, another to Tawapa, and a third through the pueblos to the gap (Walla) and the shrine called *Hopakpahoki*. The routes of these couriers were clearly indicated and could be readily followed by a line of sacred meal dropped on the ground.

[1] It is always customary before participating in elaborate ceremonials for the celebrants to wash their hair, but on this day the custom was almost universal throughout the pueblo. The name *tihüni* which is applied to this the culminating day is a contraction of a compound word meaning, we shall personate. *Tihû* is the word applied also to representations of divinities as carved images, dolls, and other similar objects. The name *Pigumnove* applies to the peculiar pudding or mush which is eaten on that day. This pudding is made for ceremonials and at no other times. Its mode of manufacture will be described in an article on "Food and food resources of the Tusayan Indians," which I have in preparation.

[2] Each chief keeps his *tiponi* ("mother") tied up in a bundle which hangs from the rafters of his house, and always carries it to the kiva when the ceremony begins. It is then placed on the altar, or forms an altar itself, for it is the most sacred of his possessions. When it is placed in position it is prescriptively placed on the junction of six radiating lines of sacred meal. When it is carried in processionals it lies over the left arm. When held upright it is placed upright in the palm of the left hand and grasped by the right. When it is laid on one side the ceremony is finished. It is held before the faces of novices in initiations. When unwrapped the occasion is one of ceremony. Each chief has a *tiponi* which is venerated for its antiquity, and is not sold or disposed of, although facsimiles are sometimes made. For the part which this object plays in the Tusayan ritual, see my articles on different ceremonies, where it is repeatedly mentioned.

The line of meal leading to the shrine of *Talatumsi* passed down the stairway or southwest trail and led to a nook in the angle between two immense boulders which were on the same terrace as the sheep corrals, about opposite the upper part of the trail on the southwestern point of the mesa.

The rough wall forming the crypt and enclosing the figurine is of undressed stone laid without mortar. A few stones were removed and the two *paho* were deposited in her girdle as I have represented them in the figure of this personage in the account of *Naacnaiya* (*op. cit.*, pl. 1, fig. 2). I was told that the Dawn woman, clothed in her white blanket, remained in this shrine throughout the year, except when she was borne to the pueblos by Kakapti and placed on the hatches of the kivas as elsewhere described.

The approach to the shrine *Hopakpahoki*[1] is about 75 yards beyond the Ute and Apache pictographs on the cliffs above the wagon road to Hano. Near that place by the side of the road there is a large boulder and a rough path ascends the cliff meandering back toward Walla, as it rises to a point above the pictographs. When the youths arrived at its termination they halted and made a little mound of meal into which they inserted twigs with feathered strings attached.

Disposal of the New Fire Embers.

Immediately after the six youths had departed with the offerings, the members of all the four societies prepared to dispose of the embers of the sacred fire in their kivas and to perform accompanying purifications. The first to observe these rites were the *Kwakwantû*, each member of which provided himself with a fragment of melon rind of proper size, and scooped up embers and ashes from the fireplace, placing as nearly as possible equal portions in all the melon rinds. The greatest care was observed to remove every particle of fire and all the ashes. Each man then took a handful of sacred meal in his left hand, and led by Anawita, the procession climbed the kiva ladder and filed to the northwest side of the court through the alley to the cliff at the

[1] *Hopoko*, N. E., *pahoki*, shrine (*paho*, *ki*, house).

west of the pueblo overlooking the ancient site of Walpi. There they halted, standing in line at the edge of the cliff facing west, each man holding the embers in the melon rind in his right hand, the sacred meal in his left. He first dropped a little meal in the fire and then waved his left hand in sinistral circuit four times above his head, and cast the remainder of the meal toward the west, after which he tossed the rind containing the embers over the cliff. This was practically performed simultaneously by all the members.

The other three societies in their respective kivas, each by itself, carefully disposed of their fire exactly as the *Kwakwantû* had done. The members of these societies passed through Sitcomovi to the summit of the ledge to the east of Walla, and there standing in line, facing west, made purifications in the same way the *Kwakwantû* had at the western end of the mesa. All the societies performed this rite simultaneously; the *Tataukyamû* and *Wüwütcimtû* standing near together as they did so. The participants were not especially costumed for this ceremony but had blankets wrapped about them. The above described purification rites were performed just before sunrise.[1]

It will be seen from the above observations that the disposition of the embers of the new fire in the different kivas is a matter of ceremony, and it is said that this purification is prescribed both in the *Wüwütcimtû* and *Naacnaiya*. In the latter this rite eluded us but it undoubtedly occurred. The manner of disposition of the new fire intimates that the embers even are looked upon as sacred,[2] and indeed it is said that direful troubles will come to any one who should light a cigarette from this fire or profane the sacred flame.

[1] While there is every reason to believe that elaborate new fire ceremonials exist in other pueblos of the southwest, unfortunately for comparative purposes, they yet await description. As I have already said (p. 193) in my *Naacnaiya* article, Mr. Hough has referred to the existence of this ceremony at Zuñi on authority of Col. Stevenson, and it is to be hoped that the exact details of this rite will be described in the articles on Zuñi ceremonials by Mr. Cushing and Mrs. Stevenson, which are expected from the Bureau of Ethnology.

[2] As I have elsewhere pointed out, all whittlings, fragments of strings, and even the bottle of some pipes used ceremoniously are not simply cast away, but are carefully gathered up, sprinkled with sacred meal, and thrown over the cliff in a manner which recalls the way the new fire embers are disposed of, except that it is generally done by the chief and not by the whole society. The idea back of both is the same, and we have similar rites in all rituals including the Christian (see piscina and its use, ecclesiastical encyclopaedias).

I am able to add from hearsay the following detail to the description of the *Naacnaiya*. On each of the three nights following the opening this ceremony occurred. When the Pleiades reached the zenith all the novices of the *Wüwütcimtû* and the *Tataukyamû* with those of the *Aaltû* were taken from the Moñkiva to the Wikwaliobi and were escorted by two *Alosaka* in single file to the spring called *Tawapa*. They all dipped their heads in this pool and stood in line along its edge. Two of them then took up some of the water in a gourd and handed it to the *Alosaka* who passed from one to another of the lads pouring a little water on the heads of all. The gourds were then refilled and a procession was formed to return to the pueblo. At the side of the trail before one mounts the terrace there is a shrine called *ü-nüñ-tañ-ü-ve* (heart contained here)[1] which lies not far from the snake house. The procession halted here and the *Alosaka* poured a little water on the head of each novice as at the pool (Tawapa). The gourd bottles now empty were given to two lads who ran back to Tawapa and filled them while the others waited. On their return the line started and filed up the trail to the terrace (*tüwive*) when the *Alosaka* again poured the water on the heads of the novices. Another pair of novices was sent back to Tawapa with the empty gourds but soon rejoined the procession which marched to the foot of the narrow stairway trail, and there one of the *Alosaka* poured water on the head of the novices from one gourd. Then all filed up the stairway to the plaza around the Moñkiva. There they stood in line between the ruinous houses on the south side[2] and the kiva hatch, and the *Alosaka* poured water upon each, after which they went down into the Moñkiva.

It will thus be seen that the pouring of water on the heads of those celebrating the new fire rites is an important feature even in the initiation of the novices.

While it is hoped that the reader may obtain from the foregoing account an outline of the new fire ceremonials at Walpi in

[1] One of the stories told of the origin of the name of the shrine *ü-nüñ pa-ho-ki*, heart shrine, is that Antelope there slew Hawk, whom he had beaten in a race, and buried his heart in that place. Before his death, the legend goes, Hawk said that all the Hopi youth who prayed at this shrine should here obtain speed and courage. This shrine somewhat resembles that called *herpatinah* at Zuñi.

[2] *Tciwüqti* (House of bird woman, the mother of Hani, who now lives in Sitcomovi).

their abbreviated form, the author makes no claim to completeness in this description. As it is intended to be a record of events, no attempt is made at interpretations, which must be delayed until the whole scheme of the Tusayan ritual is worked out. Even then we must remember that the observations here recorded were made on one of the inhabited mesas, and that there are four other Tusayan pueblos yet to be investigated. It is necessary to know something of the character of the new fire observances on the so-called middle mesa and at Oraibi before we attempt explanations, and only in this comparative way can we, I believe, advance with confidence in the treatment of the theoretical aspects of the study of rituals, for the meaning of the intricate rites which make these ceremonials the most complicated survivals of aboriginal culture remaining among the North American Indians.

General Meeting, January 16, 1895.

President W. H. Niles in the chair. Sixty-nine persons present.

Prof. E. S. Morse in a paper on Korean interviews gave many interesting details concerning the domestic life, educational methods, industries, religion, and superstitions of the Koreans.

Professor Morse also read a letter from a Korean ambassador giving the writer's impressions of America and the Americans.

Mr. Percival Lowell spoke of Korea and the Koreans, sketching briefly the geography, climate, and various physical features of the peninsula; its population and many of the peculiar customs of the Koreans were also noted.

Mr. Lowell showed a fine series of stereopticon views prepared from photographs which he had taken several years ago and of especial interest owing to the changes that will follow as a result of the Japan-China war.

The following paper was read: —

ON THE INTROITUS VAGINAE OF CERTAIN MURIDAE.[1]

BY GERRIT S. MILLER, JR.

The vaginal orifice in the smaller mice and voles is tightly closed, except when mechanically torn open during copulation and parturition. Throughout pregnancy, lactation, and the period of sexual inactivity occurring in the late autumn and winter, the *introitus vaginae* is in the great majority of individuals so completely obliterated that the region between the anus and clitoris closely resembles the perinaeum of the male. The smaller size of the sexual eminence and the shorter distance between this and the anus are the only external characters by which the females are to be distinguished from the males at times of sexual inactivity when the testes are not in the scrotum. The membrane closing the vaginal orifice is, however, always easily ruptured, whereas considerable force is required to break through the skin of the male perinaeum.

From December 20, 1890, to May 20, 1891, I examined fifty-six female mice of the following species: *Microtus pennsylvanicus* 4, *Evotomys gapperi* 11, *Peromyscus leucopus* 22, *Peromyscus leucopus canadensis* 19. All but one of the female mice taken at Elizabethtown, N. Y., during December, January, and February, had the hymen[2] perfect, completely closing the orifice of the vagina. The one exception (Peromyscus leucopus, December 21) was an individual that contained two very large embryos, and may have just given birth to others. The hymen was completely destroyed, and blood flowed freely from the vagina. The rupture and bleeding were possibly due to the pressure of the trap in which the animal was caught.

In nine Peromyscus leucopus and one Microtus pennsylvanicus taken at West Dedham, Mass., January 30–February 1, the hymen was without exception perfect.

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College, under the direction of E. L. Mark, No. XLV.

[2] This name may be used for the sake of convenience, though the structure is not homologous with the hymen.

The first broken hymen was noted on March 28 (Peromyscus leucopus canadensis, Elizabethtown, N. Y.). Of seven Evotomys gapperi taken at Elizabethtown, April 4–13, only two had broken hymens. In one of these the uterus contained three small embryos; in the other it was filled with a whitish fluid. Those with whole hymens had empty uteri. Of the fourteen Peromyscus (four P. leucopus, ten P. l. canadensis) taken at the same time and place, the majority had broken hymens, but unfortunately I did not note the exact number.

A female Peromyscus leucopus taken at Weston, Mass., May 2, showed no trace of the hymen. The uterus contained three very small embryos.

Of two female Peromyscus leucopus taken at West Dedham, Mass., May 8, one, an adult, had the hymen perfect and completely closing the vagina. The uterus of this individual contained five embryos. The other, a young one in the plumbeous coat, had a perfect hymen and empty uterus. A female of the same species taken at Provincetown, Mass., May 22, showed exactly the same conditions as the adult just mentioned. Two females of Microtus pennsylvanicus were taken on the same day. In one of these the hymen was pierced by a small opening; in the other it was complete, though retaining the scar of a recent break. The uterus of the first contained five small embryos; that of the second was empty, but retained the marks of recent placental attachments. The mammae were active. There can be no doubt that in this case the mouse had very recently given birth to young, and that the hymen had since formed so as completely to close the vagina.

These facts present the gross conditions as I have observed them in many of the smaller American Muridae and also in the European *Mus sylvaticus*, *Evotomys glareolus*, and *Microtus agrestis*.

So long ago as 1812 Legallois noticed that in the guinea pig and house mouse the vaginal orifice is usually closed. He speaks of ". . . une disposition singulière du vagin de la femelle. Cette disposition consiste en ce que l'orifice extérieur en est collé et complétement fermé. Il faut que la mâle le décolle pour que la copulation ait lieu; il se recolle ensuite au bout de trois jours; il se recolle même après l'accouchement. . . . Du reste, cet heureux

privilège d'être toujours vierge, même après de nombreux accouchements n'appartient pas exclusivement à la femelle du Cochon d'Inde; celle d'un ancien habitant de notre Europe en a aussi été gratifié, c'est la Souris."[1]

I can find no further reference to the subject until 1886 when Lataste ('86, p. 365, 366) contradicts the statement of Legallois, saying that the vaginal walls are merely approximated, the fusion being apparent only. As Lataste made no histological investigation of the subject, I doubt his conclusions. Nevertheless as his observations were made chiefly on the house mouse, a species which I have never studied, it may be that he is right, though in the closely related Mus sylvaticus I have found the gross conditions to be exactly the same as in the American Peromyscus.

No other writers have to my knowledge touched on this subject.

Histological Conditions.

(*a*) *In the adult.*

Peromyscus leucopus canadensis; a fully adult animal taken during lactation, and before marks of placental attachment had disappeared from the uterus. A few hours after death a mass of the integument surrounding the genital organs was removed; the vagina and rectum were cut at the inner surface of the skin; the whole was treated with Kleinenberg's fluid. Subsequently the material was stained *in toto* in Czokor's alum cochineal. Sections 10 μ thick were cut parallel to the sagittal plane of the body. After being affixed to the slide these were passed through 90 per cent alcohol strongly colored with picric acid. The differential stain obtained by this method is good, though somewhat fainter than might be desired.

The series of sections being perfect shows conclusively that the vaginal orifice is closed, not, as Lataste states, by the mere approximation of the walls, but by a mass of epidermal cells, which is absolutely continuous across the vaginal region.

On examination of a section passing through the axis of the vagina it is seen that the potential vaginal orifice lies close

[1] Unfortunately I have not seen the original work of Legallois, but quote the above from Lataste ('87). The passage occurs in the English translation by N. C. and J. G. Nancrede (Philadelphia, 1813) on pages 319, 320.

behind the base of the prominent clitoris and beneath a conspicuous mass of thickened epithelium. As the clitoris is directed slightly caudad, a distinct transverse groove is formed along the line of juncture between its posterior surface and that of the perinaeum. The vaginal orifice is at the bottom of this groove, in which lies the mass of thickened epithelium already referred to.

That the histological structure of this thickened region may be better understood, I introduce first a description of the normal perinaeal epidermis. This consists of three layers: stratum corneum, stratum granulosum, and stratum Malpighii. The *stratum corneum* is of the type well described and figured by Zander ('88, p. 59, Taf. 5, Fig. 1) as type B.[1] It is 18 μ thick and

[1] "Fig. 1 (Taf. V) stellt einen sehr feinen Schnitt von dem Stratum corneum der Haut der Hohlhand eines etwa 30jährigen Mannes dar. * * * Wie die Abbildung zeigt, ist das Stratum corneum aus verhältnissmässig sehr wenig abgeflachten, zellähnlichen Gebilden und nicht, wie die Schilderungen der Autoren erwarten lassen, aus völlig abgeplatteten Schüppchen aufgebaut.

Die einzelnen, die Hornschicht zusammensetzenden Elemente besitzen etwa die gleichen Dimensionen wie die Zellen in den oberen Lagen des Rete Malpighii. Sie hatten in der Mitte der Hornschicht des vorliegenden Praeparates eine durchschnittliche Länge von 0.03 mm., ihre Höhe betrug etwa die Hälfte davon und dieselben Maasse galten auch für die Zellen in den oberen Schichten des Stratum mucosum.

Ein stark glänzender, homogen erscheinender Saum grenzt die einzelnen Elemente gegen einander ab. Diese Säume verbinden sich zu einem schon bei schwacher Vergrösserung deutlichen Netz. * * *

Dieses Netzwerk besteht aus allerfeinsten Fädchen, die sich zu langgestreckten Maschen vereinen, so dass der Zellkörper ein ziemlich deutliches streifiges Aussehen zeigt. * * *

Der periphere Saum, welcher dieses feine Netzwerk nach aussen begrenzt und die einzelnen Elemente von einander scheidet, besitzt eine eben noch bestimmbare Dicke. Dieselbe beträgt nach mehreren Messungen 0.0008 mm. * * *

Ein ganz anderes Aussehen hat die Hornschicht da, wo sie verhältnissmässig dünn ist.

Sie ist zusammengesetzt aus dünnen Lamellen, die auf dem Querschnitt als feine glänzende Streifen erscheinen. Die Lamellen liegen parallel über einander geschichtet, stehen jedoch auch unter einander in Zusammenhang. Dieser Zusammenhang wird dann besonders deutlich, wenn durch irgend eine Veranlassung, z. B. das Schneiden, die Lamellen von einander abgehoben oder auseinandergezerrt werden. Alsdann kommt das Bild eines Netzwerkes zu Stande (s. Fig. 2), das gelegentlich mit dem vorher geschilderten von Hautstellen mit dickem Stratum corneum eine gewisse Aehnlichkeit erkennen lässt.

Doch sind die Unterschiede zwischen beiden so auffällige, dass von einer Gleichstellung beider keine Rede sein kann. * * *

Zur Erleichterung der weiteren Beschreibung will ich fortan diejenige Form des Stratum corneum, wie ich sie zuerst geschildert habe, als Typus A, die zweite Form als Typus B bezeichnen. Die nach dem Typus A gebaute Hornschicht ist dadurch besonders charakterisirt, dass sie aus verhältnissmässig wenig abgeplatteten Zellen besteht, welche nicht in toto verhornt sind, sondern einen Schwamm von feinsten verhornten Lamellen und Fäden darstellen. Die Hornschicht, welche ich unter dem Typus B verstanden wissen will, besteht im Gegensatz hierzu aus völlig verhornten, ganz flachen und zu Lamellen verschmolzenen Zellen.

consists of an outer lamella of cornified substance about 3 μ in thickness running parallel with the surface and joined, by exceedingly delicate oblique lamellae, with an inner lamella, not quite so thick. This inner layer is for the most part directly in contact with the stratum granulosum, but in places is separated (probably artificially) from the latter by a distinct space.

Immediately beneath the cornified layer is a tolerably well-defined *stratum granulosum* one or two cells thick. This layer is not, as stated by most authors, continuous in a given section, but appears and disappears irregularly, showing that the sheet of tissue is in reality cribriform.[1]

In none of my preparations can I find the slightest trace of a *stratum lucidum*. This, however, is to be expected, for that layer is not known to occur with the highly cornified type of stratum corneum.

The third layer, the *stratum Malpighii*, is three or four cells thick. In the more superficial layers the nuclei are scattered, occupying the widest part of the long spindle-shaped cells. In the deeper layers the cells and nuclei are more crowded, the cells of the deepest layer tending to become pavement-like in form. The thickness of the stratum Malpighii is about equal to that of the stratum corneum.

Turning now to the thickened mass at the *introitus vaginae* (Pl. 5, Fig. 2), it is seen that here also the *stratum corneum*[2] is of Zander's second type. The peripheral lamellae of this layer appear to be more affected by the cochineal than the deeper portions, as the steely blue color of the outer part changes gradually to bright yellow a little before the middle of the stratum corneum is reached, and continues so to the base. The average thickness of this layer is here about 75 μ, its individual lamellae varying from 3.75 μ to less than one third that thickness. The spaces between the lamellae vary in width from barely perceptible openings to vacuities about 7 μ in width. The lamellae are so irregular in arrangement that it is hard to estimate the exact number. There are probably about twenty.

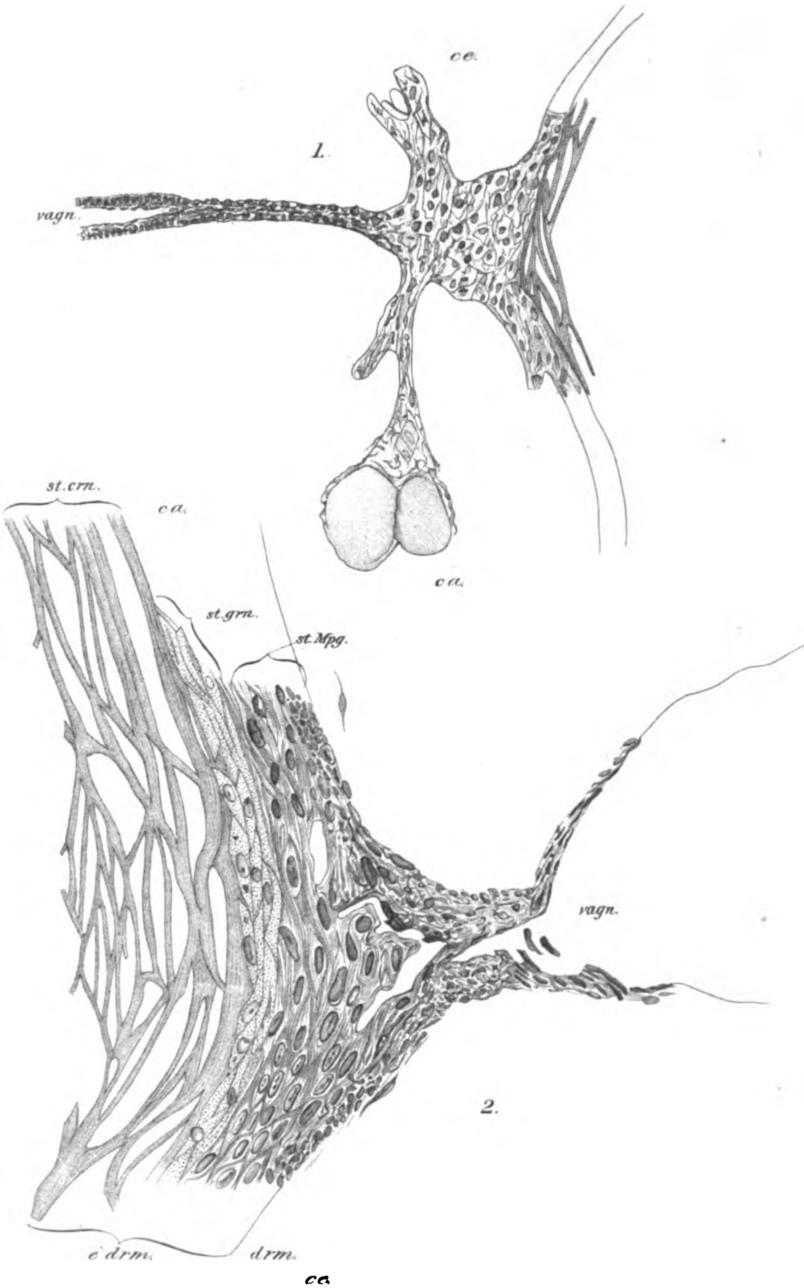
Below the cornified layer is a well-marked *stratum granulosum* from one to four cells deep. The cells of this layer appear in

[1] Zander ('88) describes the true condition.

[2] In the Plate the basal half only of the stratum corneum is shown.

sections irregularly lengthened lozenge-shaped, some of them, however, being almost fusiform in outline. They average about 22.5 μ in length and 3.75 μ in width. The cell walls are exceedingly thin and are stained pale yellow. The cell contents are very finely granular, highly refractive, and stained faintly blue. Scattered among the finer granules are numerous larger bodies of variable size. All these are, however, too small to permit of accurate measurement, the largest being less than 1 μ in diameter. The nuclei are more homogeneous in structure, and slightly more deeply stained than the cell contents. They are slightly irregular in outline and stained deep blue with a faint yellowish border. A distinct nucleolus can usually be recognized. The sides of the nuclei lie in contact with the cell walls, and their long axes are parallel with the long axes of the cells. Average length of nuclei 9.37 μ; average width 3.75 μ. The stratum granulosum is thickest and best developed immediately over the introitus vaginae, where it apparently forms a continuous layer. At either side it gradually becomes thinner until it assumes the condition seen in the normal epidermis.

Next to the stratum granulosum lies the *stratum Malpighii*. This, like the two outer layers, is greatly thickened in the region of the vagina. In the normal skin, as has already been stated, the Malpighian layer is about 18 μ thick; over the introitus vaginae it is increased to 56 μ or 57 μ. In the normal skin, again, there are only three or four layers of cells in the stratum Malpighii; here on the contrary there are ten or twelve. The thickening is due to an increase in the number of the spindle-shaped cells of the more superficial layers rather than to additions in the more crowded deeper layers. The nuclei in the stratum Malpighii are firmer in outline and somewhat more elongated than those of the stratum granulosum. The yellowish border is also more pronounced. They average about 11.25 μ in length and 3.5 μ in width. The cell walls in this region are much thicker than in the stratum granulosum, and are, together with the cell contents, stained yellow, being thus well differentiated from the pale blue nuclei. The substance of the cell is somewhat fibrous so that it is difficult to make out the cell boundaries. This difficulty increases in the deepest layers, where the cells and nuclei are so crowded that their arrangement cannot be satisfactorily determined.



G. S. M. Jr. del.

MILLER.—INTROITUS VAGINÆ.

(*b*) *In the young.*

Peromyscus leucopus canadensis; a two-thirds grown, sexually immature individual. The method of preparation was the same as in the last.

Examination with a low power (Pl. 5, Fig. 1) shows that the groove at the base of the clitoris is deeper and better defined than in the adult. The mass of epithelial cells occupying this groove has in sagittal sections approximately the form of a rough parallelogram, one side of which is the surface of the epidermis. This side and the one parallel to it are subequal in length and shorter than the sides running perpendicular to the surface. At the corners of the parallelogram farthest from the surface are the potential openings of two branched glandular structures, while between these lies the site of the future vaginal orifice.

In general the thickened epidermis in the young animal shows the same histological characters that were seen in the adult. Here also we find a stratum corneum of Zander's second type. It is, however, thinner than in the adult and is made up of rather more delicate lamellae. Beneath this is a thin, ill-defined stratum granulosum one or two cells in thickness. The cells of the Malpighian layer form the mass that fills the groove. They are less elongated than in the adult and show a slight tendency to vacuolation. In this respect they recall the conditions found by Biesiadeki in eczema nodules ('67, Taf. 3, Fig. 11).

Although this peculiar epithelial growth closes the vaginal orifice even more effectually than a true hymen, it neither contains the same histological elements nor occupies the same position as that structure. The hymen (cf. Tourneux et Legay, '84) is a membrane with epithelial tissue on each surface and true dermis within. It is produced mechanically in the development of the vagina by the very rapid increase in caliber of this tube immediately beneath the surface, the original orifice retaining its small diameter. In the tissue just described there is no suggestion of a similar condition, nor is there the least possibility that it arises in a like manner. We have to do here with a purely epithelial growth, placed immediately ectad to the region which the hymen would occupy did it occur, and which involves

neither the vaginal walls nor mesodermal tissue of any sort. It is thus impossible to homologize it with the hymen.

On the other hand the use of such a structure is not far to seek. Since in the Muridae no labia are present, the vaginal orifice is constantly exposed to injury through the introduction of particles of dust, dirt, and sand. The development of strong sphincter muscles, like those which surround the anus, would be efficacious in preventing the ingress of foreign bodies, but such a method of protection is much less likely to have been established for the introitus vaginae on account of the enormous dilatation to which this orifice is subjected during parturition. A sheet of epithelium sealing the vaginal orifice and capable of reproducing itself whenever ruptured is, on the other hand, such a simple and efficient protection that its perpetuation is readily comprehended from the standpoint of the survival of the fittest.[1] If we go farther and inquire what in the first instance may have induced in this region a tendency to exaggerated cell growth, an answer suggests itself as follows. Since mechanical irritation of epithelial tissue causes cell proliferation, it may be readily imagined that a growth of this character could be originated as the result of the action of foreign substances in the unprotected vaginal orifice. This tendency to cell growth in a definite region once established, the protection afforded by it, even though incomplete, might offer sufficient opportunity for the operation of natural selection, whereby the definite and useful structure that we now find could be perfected.

CAMBRIDGE, DECEMBER, 1894.

[1] Epithelial growths of a somewhat analagous character are met with elsewhere. During the period when the young of certain marsupials adhere to the nipples within the pouch the lips are grown together by a proliferation of epithelial cells. Thus the mouth of the helpless young animal is temporarily converted into a tube closely moulded to the nipple of the parent and furnishing a means of secure attachment (Leche, '90).

Kohl ('93) states that at one stage in the development of the eyes in *Talpa europaea* the lids are closed by a plug of epithelial cells which, however, are resorbed before birth. The appearance of this plug, as shown by Kohl's figures, bears a certain superficial resemblance to the cells of the Malpighian layer in the mass of thickened epithelium at the introitus vaginae in Peromyscus.

The temporary fusion of the eyelids in young animals, a condition which generally disappears just before or immediately after birth, is a well-known fact, whose significance in the present connection should not be lost sight of.

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EXPLANATION OF PLATE 5.

Both drawings made with the aid of an Abbé camera lucida.

Abbreviations.

ca.	Caudad.	*st. crn.*	Stratum corneum.[1]
ce.	Cephalad.	*st. grn.*	Stratum granulosum.
e'drm.	Epidermis.	*st. Mpg.*	Stratum Malpighii.
drm.	Dermis.	*vagn.*	Vagina.

Fig. 1. Median longitudinal section through *introitus vaginae* of young *Peromyscus* (view of the right face of section).

The letters *ca.* and *ce.* lie close to terminations of branched glandular structures.

Fig. 2. Median longitudinal section through *introitus vaginae* of adult *Peromyscus*, shortly after birth of young (view of the right face of section).

[1] Slightly more than one half the original thickness of this layer is shown.

General Meeting, February 6, 1895.

President W. H. Niles in the chair. Thirty-eight persons present.

Prof. W. T. Sedgwick spoke on the natural history of drinking water and of sewage, and of their purification, giving a detailed account of the methods employed and the results obtained in the bacteriological and microscopical work under his charge for the State Board of Health of Massachusetts.

General Meeting, February 20, 1895.

President W. H. Niles in the chair. Two hundred and seventy-eight persons present.

It was announced that the Council had elected Mrs. Katharine K. Wheeler, Miss Sophia W. French, and Messrs. G. F. Curtiss and C. S. Fellows Corporate Members of the Society.

Prof. Edmund B. Wilson presented to the Society the results of his investigations upon the fertilization of the ovum and other karyokinetic phenomena in the egg of the sea-urchin, *Toxopneustes variegatus*, illustrating the entire series of phenomena by means of photographs taken directly from sections of the eggs at an initial enlargement of 1,000 diameters and projected upon the screen at a much greater magnification by the means of the stereopticon. These photographs, of which over fifty were shown, were taken by Dr. Edward Leaming, of New York, from extremely thin sections, hardened in sublimate-acetic, stained with iron-haematoxylin, and projected with the Zeiss 2 mm. apochromatic oil-immersion. Many of them will be published hereafter. The paper dealt mainly with the history of the archoplasmic structures with especial reference to Fol's celebrated work on the "Quadrille of the Centres." The general results of the investigation are entirely opposed to those of Fol on every essential point; for the egg-archoplasm entirely disappears after

the formation of the polar bodies, and the cleavage-amphiaster is solely derived from or formed under the influence of the sperm-archoplasm as described by Vejdovsky in Rhynchelmis, by Boveri in Ascaris, and by Fick in the Axolotl. The sperm-archoplasm, moreover, is derived from the middle-piece of the spermatozoon; not, as Fol describes, from its tip. Identical conclusions have been reached at the same time by A. P. Mathews in the case of Arbacia and Asterias.

The history of the archoplasm has been followed out in great detail. The spermatozoon enters the egg point first, and the vitelline membrane, formed immediately afterwards, carries out with it the tail of the spermatozoon so that only the nucleus and the middle-piece enter the egg. Immediately upon its entrance the lance-shaped head of the spermatozoon rotates through an angle of about 180 degrees so that the base is finally turned inward. During this rotation the beginning of the sperm-aster becomes evident as a granular substance lying at the base of the spermatozoon and extending thence outward to the periphery of the egg as a funnel-shaped mass. From that portion of this mass that lies nearest the sperm-head astral rays are developed, extending outward into the cytoplasm of the ovum and becoming continuous with its reticulum. A careful observation of the successive stages of the rotation leaves not the least room for doubt that the sperm-aster is developed from, or under the influence of, a substance contained in the middle-piece — an observation entirely opposed to the statements of Fol upon this point.

Preceded by the aster the male pro-nucleus now moves rapidly toward the egg-nucleus which advances through the vitellus to meet it. The first contact with the egg-nucleus is effected by means of the aster; and this is followed by a contact of the two nuclei. The sperm-nucleus now flattens down against the egg-nucleus, becomes lens-shaped, and assumes a reticular structure, and the two finally fuse completely, thus giving rise to a true segmentation-nucleus in which every trace of the distinction between paternal and maternal chromatin disappears. The central body of the aster meanwhile flattens against the nuclear membrane, extends itself like a cap around the nucleus, and

finally divides into two halves which place themselves at opposite poles of the nucleus.

The rays of these asters, which are extremely long and conspicuous, stain blue in iron-haematoxylin and Congo red, and close examination shows that they are composed of minute granules or microsomes similar to those of the general reticulum but somewhat smaller. The central body of the aster stains bright red and at this period appears as a fine granular or reticulated mass. The same structure may be made out in the undivided sperm-aster from its very beginning; and a similar color-contrast appears between the rays and the central mass, though less marked than in the later stages. At their outer ends the rays branch out into the general reticulum.

The nucleus now rapidly increases in size, while the aster becomes less conspicuous. The rays become very short and more distinctly granular, while the central red-staining mass increases in size. This condition, which may be called the "pause," continues for some time (fifteen or twenty minutes), after which the cleavage-amphiaster is rapidly formed in the following manner. The astral rays rapidly extend themselves again from the central mass or archoplasm-sphere at each pole of the nucleus. Some of these rays lie within the nucleus and thus form the spindle which is directly differentiated out of the achromatic nuclear substance, and in this process the nuclear membrane apparently takes part. The chromatic reticulum meanwhile resolves itself into the chromosomes, an equatorial plate is formed, and a typical karyokinetic figure results.

During the anaphase the central red-staining archoplasm-mass rapidly enlarges, and its structure can now be very clearly seen and is shown with peculiar distinctness in the photographs. It contains no centrosomes, as figured by Fol, but consists of an irregular, fine-meshed network into which the blue astral rays are continued at their inner ends.

Throughout all of the preceding stages there is not at any time the slightest indication of an egg-centrosome or an egg-archoplasm ("ovocentre" of Fol) as distinguished from the sperm-archoplasm. The entire substance of the cleavage-amphiaster is directly derived from the sperm-aster, and this in turn may be

traced back to the middle-piece as already described. It is an interesting fact that with the double stain the middle-piece of the sperm is red while the nucleus is blue.

The closing stages of karyokinesis present many interesting features. After their divergence, the daughter chromosomes are drawn out close to the archoplasm-sphere. This is followed by a remarkable phenomenon which has not yet been carefully described although a number of authors have given a partial account of it. Each chromosome, namely, gives rise to a minute spherical vesicle, the chromatin being mainly aggregated round its periphery, while the central portion is clear. At this period each daughter nucleus, therefore, is represented by a group of vesicles equal in number (probably 38) to the chromosomes. This is followed by the progressive fusion of the vesicles, their number being rapidly reduced until only three or four remain. These finally unite to form the daughter nucleus proper, and this is followed or accompanied by the cleavage of the cytoplasm. When first formed the daughter nucleus is very small, irregular in shape, and stains very imperfectly. During the resting stage it becomes evenly rounded, rapidly grows, and the chromatin gradually resumes its staining power. The staining power of the chromatin reaches a maximum when in the form of chromosomes, a minimum in the daughter nuclei immediately after division.

The formation of the "Zwischenkörper" is clearly shown during the anaphase. It arises from a group of microsomes staining intensely blue which are derived by the disintegration of the spindle fibres; and it is an interesting and suggestive fact that the whole substance of the amphiaster, from the first formation of the sperm-aster onward, is found to consist of granules or microsomes clearly visible after treatment by various reagents (sublimate, sublimate-acetic, Flemming, etc.).

During the reconstruction of the daughter nuclei the reticulated archoplasm-sphere becomes less distinct, and the daughter nucleus is pressed closely against it or perhaps even withdrawn into its interior. The remainder of the aster (astral rays) is converted into a large blue granular mass, traversed by faint rays, which at first entirely surrounds the daughter nucleus. This mass subsequently breaks away and disappears on the

inner aspect of the nucleus (turned toward the former position of the spindle). The entire mass thus assumes a horseshoe shape in section, with the nucleus lying on its concave side. The mass finally divides upon the side opposite the spindle, and the cell passes into the resting stage, thus giving rise at each pole of the nucleus to an archoplasm-mass surrounded by astral rays precisely as in the "pause" after the fusion of the nuclei and the division of the sperm-aster. At this stage likewise the same color contrasts occur, the central mass being red and the rest blue.

Professor Wilson pointed out in some detail the bearings of these observations on those of other investigators, and upon the general question of the mechanism of inheritance. Admitting their accuracy, they would seem to afford a conclusive demonstration that the archoplasm is not concerned in inheritance since it is derived from one sex only. These investigations thus remove some of the objections that have been urged against the nuclear theory of inheritance advocated by Hertwig, Strasburger, and others, and confirm the view of Boveri that the archoplasm is essentially a dynamic element of the cell concerned with cell-division. They indicate further in the author's opinion that neither the archoplasm nor the centrosome can in any proper sense be regarded as a necessary and constant element of the cell, or even as a definite morphological body. The archoplasm is to be regarded as a differentiation of the cell-substance that under certain circumstances, it is true, may persist and be handed down by division from one cell to another, but under other circumstances may totally disappear from the cell.

General Meeting, March 6, 1895.

Vice-President Samuel Wells in the chair. Thirty-four persons present.

The following papers were read: —

ORIGIN OF THE LOWER MISSISSIPPI.

BY L. S. GRISWOLD.

That a long period of subaerial denudation in pre-Cretaceous and Cretaceous time produced a peneplain throughout the Appalachian region has become well known through the writings of McGee[1], Davis[2], Willis[3], and Hayes and Campbell[4], but that the same general surface of denudation appears west of the Mississippi is not well known, nor is the bearing of this fact upon the history of the lower Mississippi recognized. It is too commonly assumed, even in recent articles, that the Mississippi has had its present course since Palaeozoic times. Westgate[5] has indicated that such was probably not the case, and the writer wishes to present the conditions bearing upon the history of this river more in detail, now having the additional information presented by Hayes and Campbell since Westgate's article was written.

When profile sections are given illustrating the position of the Cretaceous peneplain of the Atlantic slope the surface of the plain is extended indefinitely beneath the cover of Cretaceous and later sediments; and had Hayes and Campbell presented a section extending westward from the southern Appalachians the same indefinite extension below the sediments of the Mississippi embayment would doubtless have been represented.

[1] Three formations of the middle Atlantic slope. W. J. McGee. Amer. journ. sci., 1888.

[2] The rivers and valleys of Pennsylvania. W. M. Davis. Nat. geog. mag., v. 1, p. 183–253, 1889.

The geographic development of northern New Jersey. W. M. Davis and J. W. Wood, Jr. Proc. Bost. soc. nat. hist., v. 24, p. 365–423, 1889.

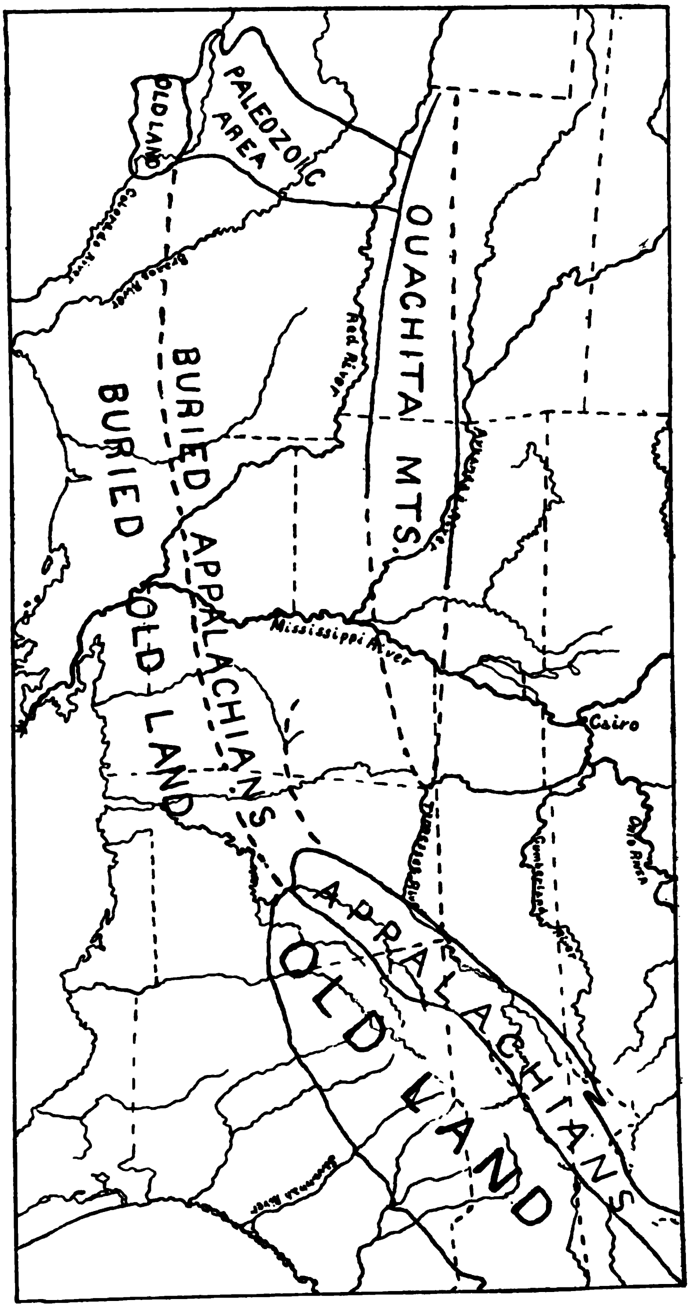
The rivers of northern New Jersey. W. M. Davis. Nat. geog. mag., v. 2, p. 81–110, 1890.

The geologic dates of origin of certain topographic forms on the Atlantic slope of the United States. W. M. Davis. Bull. geol. soc. Amer., v. 2, p. 545–581, 1890.

[3] Round about Asheville. Bailey Willis. Nat. geog. mag., v. 1, p. 291–300.

[4] Geomorphology of the southern Appalachians. C. Willard Hayes and Marius R. Campbell. Nat. geog. mag., v. 6, p. 63–126.

[5] The geographic development of the eastern part of the Mississippi drainage system. Lewis G. Westgate. Amer. geol., v. 11, April, 1893.



MAP ILLUSTRATING SOME CONDITIONS BEARING UPON THE ORIGIN OF THE LOWER MISSISSIPPI.

Here, however, we are able to identify the Cretaceous peneplain where it emerges on the western side of the embayment and so establish an identity in the geographic history of a large part of the southern United States during the Cretaceous and later cycles.

An account of the development of the Cretaceous peneplain in Arkansas has been published by the writer[1], but the essential points in its history will be repeated here. In the first place it is advocated by Winslow[2] and the writer[3] that the folded Palaeozoic strata of western central Arkansas represent a trans-Mississippian extension of the Appalachian folding, the type of folds, the date of folding, the columnar section involved, the source of the sediments, and the direction of pressure all corresponding in the two cases. Secondly, by comparing the writer's account with that of Hayes and Campbell it will be recognized that the geographic history has been similar on the two sides of the embayment. The post-Carboniferous folding of the Palaeozoic sediments in Arkansas was followed by a very long period of general erosion. The Cretaceous strata in Arkansas lie upon the upturned and eroded edges of the Lower Carboniferous group, and this gives evidence that great erosion had taken place before the beginning of Cretaceous times, an erosion measured by a columnar section perhaps four miles thick (the total of Lower Carboniferous and Carboniferous in Arkansas) with no allowance for increase in thickness of the rock mass removed given by folding which left the strata in vertical position. The Cretaceous strata were laid down upon a pretty evenly denuded Palaeozoic surface, a peneplain, for the Cretaceous border line is straight and no peaks of Palaeozoic rocks project through the Cretaceous strata south of the border line; whereas had the Palaeozoic surface been rough the border line would be irregular in outline and isolated patches of the older rocks common, since the slope of the Palaeozoic surface seems to be a gentle one. From the attitude, thickness, and character of the Cretaceous sediments we

[1] Ann. rept. Ark. geol. surv., v. 3, p. 220–222, 1890.

[2] The geotectonic and physiographic geology of western Arkansas. Bull. geol. soc. Amer., v. 2, p. 23.

[3] *Opus cit.*, p. 212–213.

may infer that they formerly had a considerable extent over the now exposed Palaeozoic rocks, and the marked discordance of streams to structure north of the Cretaceous border seems to demand an origin from superimposition[1], thus supporting the inference. North of the present Cretaceous border we now find the stripped Palaeozoic rocks presenting a very even surface, but slightly dissected by streams, and rising gradually to the north. The farther north this surface is traced, therefore the longer uncovered, the more it is found to be cut up by streams and the more dependence of the streams upon the geological structure is noticed. At a distance of fifteen to twenty miles from the border the plain as such is no longer seen, but we have the projected position of the plain surface indicated by the uniformity in the elevation of the crest lines of the ridges.

The mountain system in Arkansas above noted is believed by Branner[2] to have been an outlier of the Appalachian System which he considers to have extended farther south across the Mississippi embayment into Texas and perhaps farther. Then the mountain system thus constructed was worn down to the peneplain stage and partly buried under a Cretaceous cover. A similar relation of Cretaceous to a denuded Palaeozoic land in central Texas as shown by Tarr[3] evidences a further westward extension of similar conditions.

As the Silurian strata of central Arkansas by change in the character of the sediments indicate a derivation of materials from the south, the supposition of an old land mass in that direction, extending from the known old lands of Alabama to those of central Texas and bordering the extended and now buried Appalachians on the south, is not unreasonable. This would give not only a complete barrier to southward-flowing drainage, but would send the drainage of Palaeozoic and post-Palaeozoic time northward just as in the Virginia-Carolina region it flowed northwestward. It may be urged that such a condition is purely hypothetical and therefore of no value; still, as may be noted on

[1] *Opus cit.*, p. 218–222.

[2] Ann. rept. geol. surv. Ark., v. 3, p. 213, 1890.

[3] Notes on the physical geography of Texas. R. S. Tarr. Proc. acad. nat. sci. Phil., 1893, p. 317–318.

the map, the necessary extension eastward under the Mississippi embayment of the folded Palaeozoic rocks of Arkansas must have been an effective barrier to southward-flowing drainage for some time after the completion of the folding. It is true that the folds do not connect in an axial line with those of the Appalachians, but as the dips of the strata are steep where last seen before covered by the Cretaceous and later sediments, the system of folds must extend far before dying out; indeed, the disturbances noted by Hilgard[1] in the Lower Carboniferous rocks of northeast Mississippi may indicate the extreme end of the system. Continuing from northeast Mississippi the rocks of northern Alabama belong to the base of the Lower Carboniferous with the Silurian exposed in patches; thus the line of uplift is continued, and it is not until northeastern Alabama is reached that a depression in the old line of disturbance is indicated by the occurrence of the Carboniferous series. In northeast Alabama, then, was the most probable outlet for southward-flowing drainage if such existed in pre-Cretaceous times, but as the Cumberland River, regarded by Hayes and Campbell as antecedent in origin, now crosses this axis of depression farther to the north we may believe that no great river formerly held a southward course along it.

If then the lower Mississippi did not exist at the close of Palaeozoic time, when and how was its course gained? We may learn this by following the geographical history farther. The Cretaceous peneplain in Arkansas dips gently eastward and in Alabama westward beneath the sediments of the Mississippi embayment, and presumably the peneplain surface is continuous. But if there is here a buried peneplain there was formerly an old land mass subject to subaerial denudation, and this denudation continued from the close of Palaeozoic time into the Cretaceous; thus the land of the present region of the lower Mississippi was presumably above water during this time and would have remained a barrier to an escape of drainage from the north.

[1] Agriculture and geology of Mississippi, 1860. On page 47 he states: "It is more difficult to ascertain the order of superposition of the several strata, because in different localities they appear partly horizontal, partly at various inclinations to the horizon, in opposite directions." As he records no dips but to the north and south, east and west axes of deformation are indicated, thus corresponding with the Arkansas system.

The occurrence of Permian and earlier Mesozoic strata in the west would indicate the presence of a sea basin in that direction into which the drainage of the upper Mississippi valley could escape, thereby obviating any necessity for escape southward.

During Cretaceous time the peneplain was submerged on its southern side and received a cover of Cretaceous sediments which are known up the Mississippi embayment nearly to Cairo. As evidence is wanting that the Cretaceous sediments ever had a much wider extent than is indicated by the present form of the embayment we may infer that the peneplain was warped at the time of submergence and that the form of the Mississippi embayment was given early in Cretaceous times. Having in this way introduced the ocean level to the vicinity of Cairo and having the head of the embayment surrounded by a peneplain surface warped with a gentle slope toward the embayment, it is an easy step to consider either that the drainage of the upper Mississippi basin was turned into the embayment as a result of the warping or that a stream working backward from the head of the embayment captured the interior drainage.

In this way a rational explanation is given for the occurrence of the lower Mississippi in it's present position, and while it is not possible to adopt the explanation as a complete demonstration, yet it is much superior to an assumption that the river has been where it is now, since the close of the Appalachian revolution.

THE GEOGRAPHIC DEVELOPMENT OF CROWLEY'S RIDGE.

BY C. F. MARBUT.

Crowley's Ridge is a long, narrow belt of upland, lying within a large area of lowland in northeastern Arkansas and southeastern Missouri. It extends in a slightly crescentic form from the Mississippi River near Cape Girardeau, Missouri, southwestward to Helena, Arkansas. It is limited on its eastern side by

the wide lowland constituting the flood-plain of the Mississippi River and on its western side by a somewhat similar lowland belt, along which White River and some of its principal tributaries flow. The lowland on the east separates the ridge from the Tertiary uplands of western Kentucky, Tennessee, and northwestern Mississippi. The width of the flood-plain varies from 20 to 40 miles. The lowland on the west separates the ridge from the Palaeozoic uplands of Arkansas and Missouri by a distance varying from 5 to 40 miles.

From Helena northward[1] to the St. Francois River the ridge is broader and higher than anywhere else, the highest part being along the western side which here has an elevation of a little more than 200 feet above the flood-plain of the Mississippi River.

From the crest the western side descends abruptly to the lowland and the eastern side slopes gradually eastward to the top of the bluff overlooking the Mississippi River flood-plain and then descends abruptly.

North of the St. Francois River the ridge is broken up into many small ridges which approach much nearer to the Palaeozoic highlands than further southward, thus making the lowland west of the ridge much narrower.

Figure 1 is a diagrammatic representation of the northern part of the Mississippi embayment. Crowley's Ridge is shown as a heavy dark line. The shoreward limit of the Palaeozoic uplands running around the embayment is indicated by a dotted line running northeastward west of Crowley's Ridge, crossing the Mississippi River near Cape Girardeau, Missouri, and extending eastward and then southeastward beyond the Tennessee.

The prominence of the ridge, a very narrow belt of upland in a wide area of very low and flat country, has attracted much attention and various hypotheses have been advanced to explain its existence. Three of these will be noticed here.

The first is that advanced by Dr. John C. Branner, state geologist of Arkansas, who supposes that the ridge is a residual of the coastal plain left as an upland by the erosion of the material from all around it by the Mississippi and Ohio Rivers. He

[1] The facts concerning Crowley's Ridge were obtained mainly from Prof. R. E. Call's report on that area. Annual rept. geol. surv. of Ark. for 1889, v. 2.

supposes that the Mississippi River formerly flowed around to the west of the ridge, excavating the lowland now lying on that side of it, and that the Ohio River at the same time flowed along the eastern side of the ridge excavating a part of the present valley of the Mississippi, and that the two rivers united somewhere south of where Helena, Arkansas, now stands. Subsequently the Mississippi River cut through the ridge where the St.

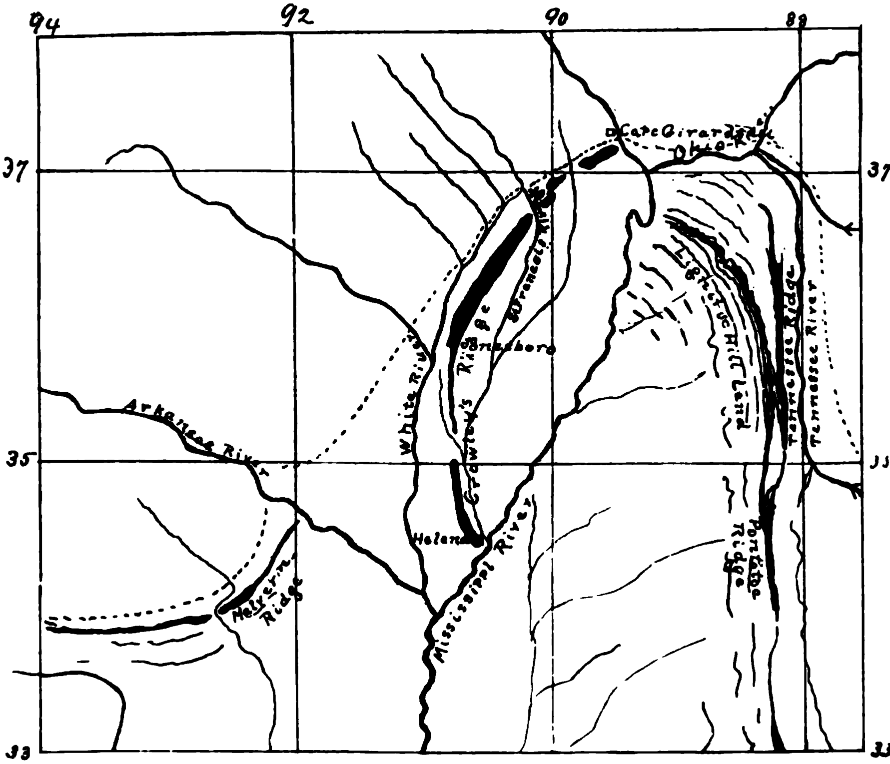


FIG. 1. Northern part of the Mississippi embayment.

Francois now crosses it and also where Little and Castor Rivers traverse it in southeastern Missouri. Finally the Mississippi River abandoned this channel altogether and adopted its present course.[1]

[1] Ann. rept. geol. surv. Ark. for 1889, v. 2, p. xiv. Introduction.

Another hypothesis is that advanced by Prof. R. E. Call, formerly assistant geologist on the Arkansas geological survey. He supposes that, at the time of the uplift of the Atlantic and Gulf coastal shelf into the present coastal plain, the Mississippi River separated into at least two distributary branches at the head of the embayment, one of which flowed southward, west of what is now Crowley's Ridge, excavating the lowland belt on its western side, and the other flowed more directly southward along the present course of the Mississippi River. Subsequently the valley west of the ridge was abandoned and that part of the river joined the other, forming the modern Mississippi.

The other hypothesis is that of the writer who supposes, with the others, that Crowley's Ridge is a residual of the coastal plain sediments left in relief by erosion of material from all sides of it, but differs from the others in supposing that the lowland belt lying along the western side of the ridge is a subsequent lowland, worn on weak rocks by the streams now flowing in it, and that the only work that has been done directly by the Mississippi River is the excavation of the valley along the eastern side of the ridge.

In order to show the reasons for this explanation it will be necessary to call attention to some of the features, in the mature stage, of the topographic development of a coastal plain.

On the uplift of a part of the continental shelf into a coastal plain, of the Atlantic or Gulf coast type, the rivers draining the old land and formerly entering the sea at the inner margin of the coastal plain will be extended across the latter to its present shore line as new consequent streams. The rocks making up the coastal plain will be composed of strata of varying resistance to erosion dipping gently seaward. If the slope of the surface raised above sea level be greater than the grade of the largest streams extended across it, as is usually the case, the first work done upon it will be a channeling of its surface. The larger streams will soon cut their channels down to grade. In doing so they will encounter certain harder strata of the coastal plain, but the largest of the streams will not be greatly delayed by them. The smaller streams, however, will be greatly retarded,

or at least more so than the larger ones. The result will be that the larger streams will reach grade long before the smaller ones have, and even if they do not, their slope at grade will be so much smaller than that of the smaller streams that at a little distance inland from the coast their channels will be lower than those of the latter. This gives the subsequent branches growing headward from the large streams inland from the outcrop of the hard member or members a great advantage over the similarly related branches of the smaller streams. A small subsequent branch of a large stream growing headward along the strike of the soft beds, inland from the outcrop of the hard ones, may grow headward so rapidly, on account of its advantage of a low outlet through the hard rocks by way of the channel of the large stream, that it will finally reach back to a smaller originally consequent stream and, by offering a lower outlet to the sea, capture its head waters.

This may occur on both sides of a master stream and may extend to all the originally consequent streams for a considerable distance.

The final result will be the formation of alternating belts of lowland and upland running along the strike of the rocks approximately parallel to the old coast line, drained transversely by a few large streams which have maintained their way through the hard rocks and have captured the head waters of most, or all, of the smaller consequent streams, causing them to flow along the lowland belts and seek an outlet through the gap in the upland made by the larger streams.

The upland will fall more or less steeply as an escarpment or rather steep slope on the landward side to the adjacent inner lowland, and slope gradually on the seaward side, either into the adjoining lowland belt or to the coast. The lowlands will be abruptly terminated by the steep face of the upland on one side and more gradually by the gradual rise to the upland on the other.

At maturity the features will be about as shown in Fig. 2. A is the master stream of the area. It has captured the head waters of the small consequent streams *a*, *b*, and *c*, diverting them to an adjusted course along the inner lowland and taking

them through the upland belt by way of its own gap. The gaps in the upland made by the smaller streams before their headwaters were captured still exist as shallow notches.

If the original consequent streams were all of about equal size, no captures would occur though the lowland and highland belts would be developed the same.

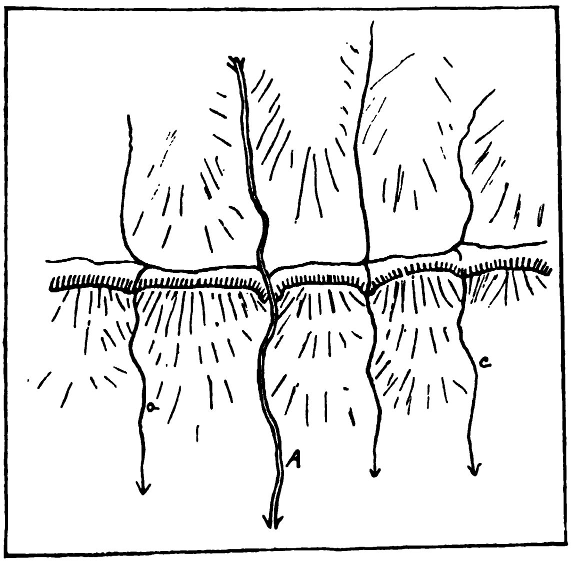


Fig. 2. Diagram showing adjusted drainage.

The case shown in Fig. 2 is the simplest case possible. If the original shore line were irregular instead of, as in the ideal case, straight, there would be some modification of the resulting forms. Or by varying some other factor the result will be slightly modified.

In the simple case the diagram of the adjusted drainage is rectangular. If, however, the coast line had been convex landward, forming an embayment and thereby causing the outcrop of the strata to have a similar occurrence, the diagram of the adjusted drainage would be as shown in Fig. 3.

Again, if the hard member of the coastal plain were more resistant on one side of the master stream than on the other,

we might have perfect adjustment of the drainage on the side where the hard member is most resistant, and but little or no adjustment on the other. If, however, the resistant member on the latter side is more resistant than the underlying soft member, the development into a lowland and a highland belt will occur the same. A smaller stream entering the master stream from the side having the weaker resistant member may succeed in capturing the adjoining small streams before subsequents from the master stream reach them.

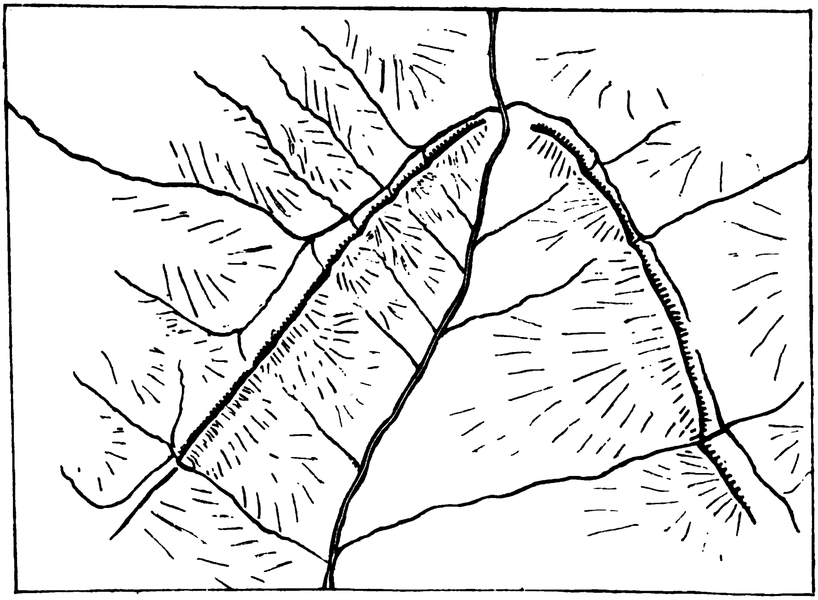


FIG. 3. Diagram showing adjusted drainage.

These features are characteristic under the conditions assumed, and are persistent, at maturity, over the whole length of coastal plain furnishing the proper conditions.

In applying this, now, to the question of the origin of Crowley's Ridge and the lowland along its western side, it will be necessary, in order to show that my interpretation is correct, to show that the features there exhibited are only parts of more or less continuous features of the same kind extending around

the inner border of the embayment, though the local facies in different parts may vary slightly from each other and from the type.

The wide lowland west of the ridge apparently turns around the southern end of the ridge and joins the lowland of the Mississippi River flood-plain.

By means, however, of the best maps obtainable and from the description of the inland border of the coastal plain southwest of Little Rock, Arkansas, it is clear that there is a well-defined lowland belt extending in that direction holding the same relation to the coastal plain as the lowland west of Crowley's Ridge. It extends from Little Rock southwestward, faintly defined at first but becoming more and more pronounced southward to Malvern. Here the Ouachita River enters it from the Palaeozoic uplands, turns abruptly along it in a southwesterly direction to Arkadelphia, where it turns abruptly to the southeast and escapes from the lowland through a gap in the Tertiary upland. The St. Louis Iron Mountain and Southern railway follows this lowland from Little Rock to Arkadelphia. From the latter place the lowland belt turns westward along the border of Mesozoic rocks to western Arkansas. It was first clearly recognized and described in this area by Prof. Robert T. Hill.[1]

Crossing the Mississippi River at the head of the embayment a lowland belt, occupying the same relation to the coastal plain, extends along the valley of the Ohio River to the mouth of the Tennessee; thence southward as the valley of the latter stream to northeastern Mississippi; thence southward in the flatwoods region of Mississippi, and the lowland inland from the Chunnenugga Ridge in Alabama.

The lowland west of Crowley's Ridge is seen, therefore, to be only a part of one continuous feature extending from southwestern Arkansas to eastern Alabama.

Similarly Crowley's Ridge has its homologue in the Lignitic Hill Land[2] of Kentucky, Tennessee, and Mississippi; the Tennessee Ridge[3]; the Pontotoc Ridge and Noxubee Hill Land of Mississippi and the Chunnenugga Ridge of Alabama. South-

[1] Ann. rept. geol. surv. Ark. 1888, v. 2, p. 11-12.

[2] McGee, Twelfth Annual report U. S. geol. survey, p. 366.

[3] Safford. Geol. of Tennessee: Section on geological map of the State.

westward it is continued in what I have called the "Malvern Ridge" and the Tertiary uplands north of Red River in western Arkansas. All these features are shown diagrammatically in Fig 1.

The fact that Crowley's Ridge and the lowland along its western side are parts of continuous features lends support to the view that they were all similarly developed, and the close relation of the whole to the ideal scheme, with some local variations, lends support to the view that they were all developed according to the scheme.

One of the variations of the scheme is the course of White River along the lowland. Instead of turning northeastwardly on entering the lowland belt and flowing into the Mississippi River at the head of the embayment, it turns southwestward and gradually southeastwardly and flows into the Mississippi south of the ridge. Its course suggests a southward diversion by capture by some stream to the south of it. The only stream at all capable of doing it is the Arkansas, a stream smaller than the Mississippi at the head of the embayment. Two things may have aided the Arkansas in doing this: 1. The constructional slope of the embayment on this side was to the southeastward. 2. The hard member (the lignitic) of this part of the coastal plain was evidently much less resistant here than elsewhere. I am, however, not prepared to say that the present lower course of White River is not its constructional course.

Some features of the lowland west of Crowley's Ridge and of the ridge itself seem to indicate that no large stream ever flowed around west of the ridge. These are the nature of the lowland, and the attitude of certain streams.

The lowland is more than 40 miles wide at the southern end of the ridge, but northwardly its width decreases gradually to Stoddard County, Missouri, where it is not more than five miles wide. If it were a part, now abandoned, of the flood-plain of a large stream, it would have approximately the same width along its whole course unless there were a considerable difference in the resistance of the rocks at different places, but here the strata making up the ridge seem to be least resistant just where the lowland is narrowest.

Again, the lowland is not a perfectly flat stretch like the flood-plain of a large stream, but is a slightly uneven one. Its surface is varied by small hills and ridges such as Cypress Ridge, Jones Ridge, Negro Hill, Augusta Ridge, Duvalls Bluff, and many others, giving a maximum variation of relief of nearly 100 feet.

The attitude of the St. Francois and L'Anguille Rivers indicates that the lowland was not excavated by one large stream. They both maintain their courses across the ridge. If a large stream had excavated the lowland and had subsequently abandoned it, these streams could not have crossed the ridge. Streams cannot plow their way through an unbroken upland from one lowland to another. They can act only as saws and must commence on top of the upland.[1]

In order to get these streams across the ridge we should have to suppose that the Pleistocene deposits filled up all the pre-Pleistocene inequalities and that these streams on reëmergence were superposed on the ridge rocks.

A relation of master stream, inner lowland, and inland-facing escarpment, similar to that existing in the Mississippi embayment, exists in the coastal plain region in the northeastern part of its extent in the United States. The Hudson River is the master stream of the area, corresponding to the Mississippi River in the embayment. The inner lowland, corresponding to the lowland west of Crowley's Ridge, is the lowland belt extending from New York City southwestward by Trenton, Philadelphia, and Baltimore. The Delaware and Susquehanna Rivers are here deflected along the lowlands as are the White and Ouachita in Arkansas. Eastward from New York City the lowland corresponding to that on the eastern side of the Mississippi embayment is submerged in Long Island Sound. The coastward upland in this case, corresponding to Crowley's Ridge and its homologues in the Mississippi embayment, are the Cretaceous uplands of Long Island, New Jersey, and eastern Maryland. The same features continue further southward also.

The foregoing is the result of study pursued in the geographical laboratory at Harvard University under the direction of Prof. W. M. Davis. Field study may cause some modification of the views herein expressed.

[1] It is of course possible for a stream to sap its way through a narrow upland but there is no evidence in either case here that this has occurred.

REMARKS ON THE CUSPATE CAPES OF THE CAROLINA COAST.

BY CLEVELAND ABBE, JR.

In presenting this short paper I must acknowledge my indebtedness to Prof. W. M. Davis for many suggestions, comments, and discussions, and ought to say that the greater part of the paper was worked over last year, under his guidance.

Introduction. — Along the Atlantic coast of North America from Cape Ann to the Florida Keys, and also along the Gulf coast of Texas, there extends a belt of sandy off-shore bars or beaches occasionally interrupted by short stretches of low cliffs.

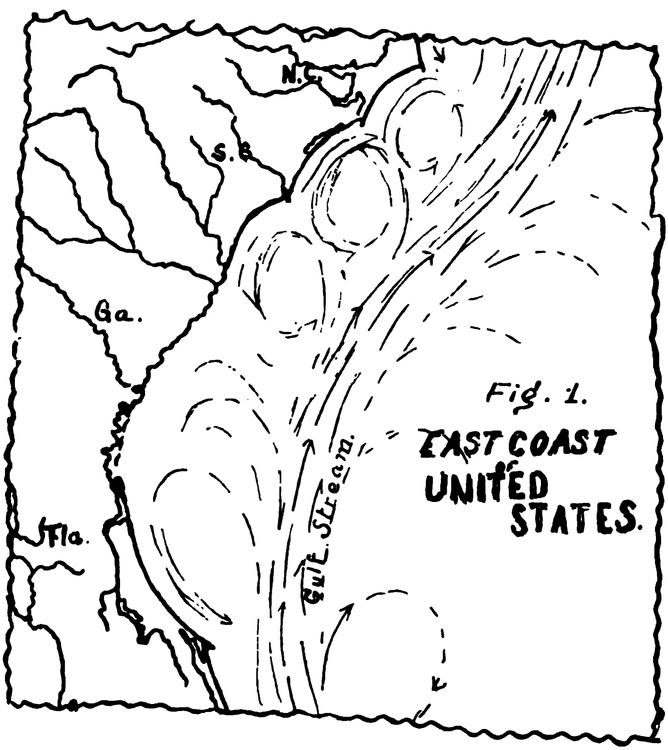


Fig. 1.
EAST COAST UNITED STATES.

The bars serve in general to protect from the sea the much more irregular and indented shore-line of the mainland, while they themselves present a much simpler coast-line.

Behind these bars we generally find a system of tidal marshes or shallow lagoons of varying width, but rarely exceeding 20 or 25 feet in depth. The sandy beaches outside are worthless for cultivation, but the marshes yield a coarse salt hay prized by cattle; while with the aid of some canals the lagoons have been converted into inland waterways that afford safe passage to small vessels bound up or down the coast.

It will be interesting then to study the formation of these natural breakwaters, more particularly since our special study is of those dangerous Capes, Hatteras, Lookout, and Fear.

Formation of the bars.— Wherever these bars occur we also find a broad, comparatively shoal bench of detritus bordering the coast-line (on the east). Over this shelf the water gradually deepens to about 100 fathoms, after which the descent is much more rapid to the oceanic depths.

The great Atlantic rollers rolling in over this bench or continental shelf, and stirring up the bottom, carry with them the material thus worked on. Part of this detritus is thrown up by the waves where they break and thus forms a bar, while the other portion is carried out by the undertow and serves to shoal up the deeper water. This shoaling of the deeper seaward waters causes the waves of the next storm to break a little further out. Thus there will be built out a series of bars until a depth is reached where the waves no longer stir up the bottom but work directly and wholly on the beach. From this stage onward the waves are working to cut away the bars and force the coast-line shoreward. Just enough waste will be carried seaward to keep the submerged slope at an angle up which the waves may run without breaking until they reach the beach. This line along which the waves first acted, and which later was perhaps moved seaward for a time, but now again moves landward, may be called the *locus of maximum activity* of the waves. Plainly this line is not a fixed one, but must vary with the size of the waves, depth of water, and composition of the bottom.

All the material of the beaches does not, however, come from the bottom. Where the mainland has a sufficient depth of water off its coast the waves have attacked it directly and carved out cliffs, or the landward migrations of the bars may cause the locus of maximum activity to intersect an irregularity of the mainland coast and thus a cliff is formed flanked by sand bars. In either case, tidal and other currents moving along the face of the cliff transport a portion of the debris from it to the beaches and bars forming on either side, while the remainder is carried seaward or remains as a beach in front of the cliff. These currents may be of tidal origin or they may be set up by winds or by waves coming obliquely to the coast, as the Atlantic rollers do on the Carolina coast.

Along our Atlantic coast the general drift of these long shore currents seems to be southerly. This conclusion is reached because as we go southward we find that the quartz grains of sand lose the angular shape they have in the north and become more and more rounded. Again, observations on the passages, kept open through the bars by the tide, show that they also tend to migrate southward. Professor Shaler says[1]: "In the longest connected lagoon of the American coast — that on the eastern shore of Florida known as the Indian River — each inlet, for the reason that the sands of the island beaches are constantly moving southward, gradually travels in a southerly direction until it abuts against some obstacle. Then the further incursion of sand from the north closes the opening" (p. 126). "The southward movement of the sands along this shore is indicated by the existence of hooked spits, such as that at the south end of Chincoteague Bay, and again in a more extensive way at Cape Charles" (p. 175). Speaking of the sand on Cape Florida he says: "At this extreme southern position the quantity of the sand is not great and the grains of silex of which it is composed are much rounded by their long and arduous journey . . ." (p. 128).

This current with its load of sand, by dropping some here in a hollow or cutting away part of some irregular protrusion, eventually establishes, along the seaward face of cliffs and bars, an

[1] Thirteenth annual report, U. S. geol. survey, for 1891-92.

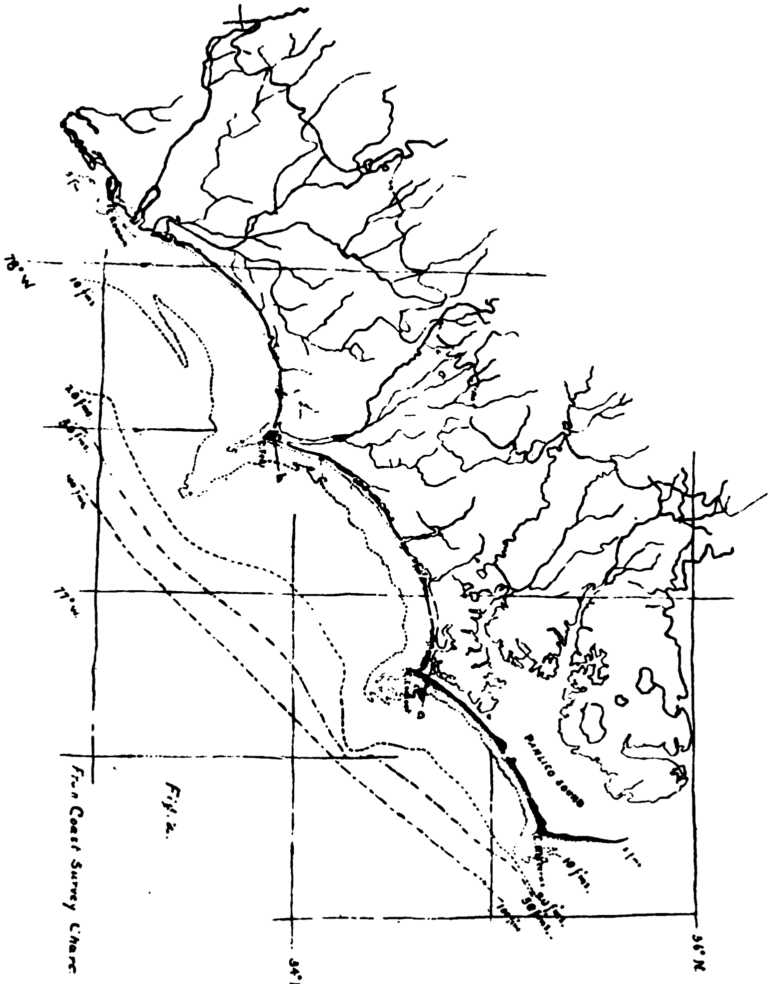
evenly graded course along which it is able to maintain a speed sufficient to carry its load. In this respect the seaward slope and the shorewise contours of an evenly contoured coast may be likened to the graded course of a river-bed that has been built by the river to such a slope or grade that the given volume of water flowing over it can just carry its given load to the lake or sea into which it empties.

When the waves and currents have built up the bars so that they are laid bare at low water and can dry off on the surface, then the winds begin to heap the sand into dunes or blow it across into the shoal waters of the lagoons. The winds also carry a small portion of the dune sand into the sea. Thus the bars, showing above water as beaches continuing the line of the cliff-fronts, show us the line of maximum activity of the marine forces, whose motion is, on the whole, landward.

Behind the beaches the shallow, quiet lagoons of imprisoned waters are continually receiving the detritus brought down by the rivers, and also the sand that is blown inland from the beaches. The lagoons, then, would soon become completely filled were it not that the constant ebb and flow of the tides has kept open inlets through the beaches and thus maintains channels in the lagoons behind. The constant tidal current through these inlets serves to interrupt the progress of the long shore currents, and these, being deflected in or out, deposit their load of sands in the form of tidal deltas both inside and outside the opening of the inlet. Over these deltas the sands wander in shifting paths until they finally reach the further side of the inlet and again continue their coastwise travelling.

On the whole, we may say that the sea is constantly working to even off the coast-line, cutting in and forming cliffs on the headlands, and strewing the waste thus formed beyond the cliffs in confluently curving beaches or bars that straighten out as the cliffs are cut back. Such being the usual development of a "cliff and bar" coast we are now to seek some explanation for the aberrant type found along the Carolina coast. (See fig. 2.)

The most striking feature of the beaches on the Carolina coast is that they meet in cuspate points forming the three Capes, Hatteras, Lookout, and Fear, while Cape Romain faintly



suggests a cusp. The three capes first mentioned have long shifting shoals extending seaward from their cusps, and closer examination shows us that the capes and their attendant sand shoals have a distinct, well-marked tendency to run southwestward.

Again, taken as a whole, we find the marshes that are forming behind the capes to be notably nearer the northeast strands than

the southwest strands of the capes (see a, b, c, fig. 2). In two cases (fig. 2, b and c) this approach of the marsh to the water-line is so far advanced that the marshy formation is itself washed by the waves and forms a low escarpment. These two cases are those of the beach just east of the Cape Fear River and the east shore of the island at the mouth of the same river. With respect to the former point, Professor Shaler says[1]: "The beach is continuous around the sweep of the curve to near the mouth of Cape Fear River, where the barrier of sand is replaced by a shore escarpment."

Cape Lookout is further characterized by a hooked spit that has been built at an angle to the general trend of the cape and points shoreward.

Inference as to movement. — From these observations we are led to infer that the strongest or the most persistent currents on this coast have a direction from northeast to southwest. The approach to an exposure of the marshes on the northeast side of the capes and the actual exposure of them in the case of the Cape Fear district shows us an evident cutting by the waves on this side of the capes, while deposition is shown on the opposite shores by the sand beaches there forming. Finally the evidence of continued southwestward growth, as shown by Cape Lookout that has a spit continuing beyond the hook already referred to, when taken with the above evidences of southwestward cutting, all leads one to conjecture that these cuspate capes are slowly traveling southwestward.

Explanations offered. — Mr. G. K. Gilbert in his monograph on Lake Bonneville describes V-shaped embankments and bars where "in most cases, the shore drift appears to have been carried by one current from the mainland along one margin of the terrace (embankment) to the apex, and by another current, along the remaining side of the terrace back to the mainland" (p. 57). These bars described by Mr. Gilbert are lacking in the sharp, cuspate outline, the continuing shoals, and the hooked spits of the Carolina capes, hence the above explanation does not fit our case very well.

Mr. Tuomey, former state geologist of South Carolina, observes

[1] *Opus cit.*, p. 179.

that "the fine matter held in suspension by the river water, as it enters the ocean, would be dissipated by the currents along the coast, if a barrier were not raised by the ocean itself, which breaks the force of these currents, and produces still water between the beach and the coast.

"The Gulf Stream produces an eddy current which washes the coast southwardly, and the sand bars, so common on the coast, are formed in the diagonal or resultant of these two currents. Those formed at the mouth of rivers must also, it seems to me, be influenced by the force and direction of their waters. These bars, however, are generally formed directly by the ocean, and not by the waters of the rivers."[1]

So we find that though he has observed the building of the bars and also found a southward flowing eddy current from the Gulf Stream, nevertheless Mr. Tuomey has not attempted to explain the cuspate form of the capes along neighboring shores, nor does he seem to have observed any southward shifting of their positions.

The latest mention of these capes that I have been able to find is made by Prof. N. S. Shaler in a paper[2] on the "Geology of Harbors," printed in 1894. In this paper he explains that "their origin is probably due to original slight inequalities in the coast-line, which have been developed in regular curves by tidal action. At the inner part of each reëntrant the rise of the tide is considerably greater than upon the neighboring horns of the bay. The result is that the tide works most effectively in the bottom of the curve and by its movement serves to convey the waste to the capes on the north and south. An evidence of this action is shown by the fact that the water is tolerably deep almost to the shore-line in the center of the curve and is prevailingly made more shallow by the occurrence of sand bars near each salient."

That such currents as these exist and exercise some influence on the building of the bars and beaches is no doubt true; but it does not seem to me that they account for all the facts we have found. That is, such a set of currents does not seem to explain the regular cutting on the northeast shores of the capes, their

[1] Tuomey. Geol. survey of S. Carolina, 1848, p. 190.

[2] Thirteenth annual report U. S. geol. survey for 1891-92, p. 180.

movement southwestward, nor the hook-spit form of Cape Lookout.

Referring to this hook-spit form, its growth may be described as follows: A current flowing in one direction is met by a cross current. Thus the spit the first current was building is made to turn when it meets the second current and grow in the direction of flow of the temporary or vacillating cross current. When this latter current loses a part of its strength the spit begins to grow forward again in its former direction, leaving the hook behind to mark a stage in its progress. Thus to explain the formation of the hook-spit on Cape Lookout we need another current flowing almost perpendicularly to the one flowing along the northeast shore of the cape, and its direction must be landwards. But Professor Shaler's explanation would seem to give us a current, crossing the southwesterly one to be sure, but flowing *seaward* instead of landward.

Finally, though Professor Shaler's explanation be found to give a series of cuspate capes on these shores, it seems to me more probable that if due to tidal currents, they would have the more blunted form seen in Cape Canaveral on the coast of Florida, rather than the form here considered where the southwestward moving current seems in each case to have built the beaches right across the curve of the succeeding western shore; just as if the one beach were now cutting right across part of the other beach. This seems hardly to be the result of two currents such as Professor Shaler describes.

A satisfactory hypothesis must then account for the southwestward intention of the cuspate capes, the evidence of inflow at the hook, and the tendency of the capes to travel southwestward.

It is therefore suggested that a set of back-set eddies (see fig. 1) is here produced by the northeastward-flowing Gulf Stream, and that these eddies, aided by waves from the prevailingly northeast and southeast storms of this area, have produced the cuspate capes which we have studied. The currents of the back-set eddies setting from northeast to southwest would serve to determine the general trend of movement and of cutting, and would also explain the cross currents that formed the hooked-spit of Cape Lookout. (See fig. 1.)

As to the actual existence of such a set of eddies on this portion of the coast, though not rigidly proved, we may with some show of reason infer that they exist. For on other parts of our own coast and on foreign coasts,[1] such as along the south coast of Alaska, and on the northern coast of the Isthmus of Panama, we find such eddies set up by the great ocean currents. And, moreover, we have Mr. Tuomey's observation of such a current flowing along the coast of South Carolina.

Our assumption, then, of a set of back-eddies is not a violent one, and it seems to suit our needs better than previous explanations.

General Meeting, March 20, 1895.

Vice-President W. G. Farlow in the chair. Thirty-eight persons present.

The death of George N. Lawrence, of the Marquis de Saporta, and of Isaac Sprague, Corresponding Members of the Society, was announced.

Miss Grace E. Cooley read a paper on the reserve cellulose of the endosperm of seeds of the Liliaceae and of some allied orders. (See Memoirs Boston soc. nat. hist., vol. 5, no. 1.)

General Meeting, April 2, 1895.

President W. H. Niles in the chair. Sixty-one persons present.

Prof. Harold C. Ernst spoke on the antitoxine of diphtheria.

General Meeting, April 17, 1895.

President W. H. Niles in the chair. Two hundred and eighty-four persons present.

[1] See a chart of ocean currents published by Dr. O. Krummel in 1886 for the "Anleitungen zu wissenschaftlichen Beobachtungen f. Reisenden."

The President remarked that death had deprived the Society of one of the most illustrious of its Honorary Members, Prof. James Dwight Dana of New Haven.

He was elected at the meeting held Dec. 19, 1866. When he had accepted and his name had been enrolled in her list of members, it was the Society which had been honored, for he was already well known as a distinguished naturalist. The twenty-nine years of his life which remained have continually added to his renown and to our gratification. In 1892, the Society had the privilege of awarding the Grand Honorary Prize of one thousand dollars to Professor Dana for extraordinary merit of investigation and discovery in natural history.

To become a master in one branch of science is now justly regarded as an honorable achievement, but Professor Dana was a master in each of three grand divisions of natural history, in zoology, in mineralogy, and in geology. The remarkable range of his investigations, the magnitude of his scientific publications, and the importance of his deductions and discoveries clearly placed him among the great naturalists of the world.

The numerous and sometimes imperial volumes in which many of the results of his studies have been recorded had been placed upon the table. While recounting his labors as a zoologist, a mineralogist, and a geologist Professor Niles spoke of the larger of his works in each science in the order of their publication, and he called attention to the large number of plates drawn by Professor Dana for the folio atlases of his great works upon Zoophytes and Crustacea. He also mentioned the long list of his scientific papers, especially noticing certain series of them which had been collected into volumes, as those upon Taconic rocks of the Green Mountain region, The Quaternary in New England, The volcanoes and volcanic phenomena of the Hawaiian Islands, and The classification of animals based on the principle of cephalization. He also referred to his multiplied contributions to the American journal of science and other current publications. He was also a careful and painstaking worker, and his voluminous writings are to be valued for their completeness and accuracy. His well-done work was frequently revised, and the new editions of some of his books show how constantly he read,

thought, and progressed in those subjects upon which he had written in a masterly manner.

So well did he know the needs of the advanced student and the worker and so successfully did he labor for their good, that, in our country, the mineralogist cannot work long without Dana's Mineralogy, and the geologist must waste time if he does not have ready access to Dana's Manual of geology. The fourth edition of this Manual is the last published production of our distinguished friend. For months geologists have quietly asked, Is it probable that Professor Dana will survive to see the completion of the new edition of his geology? The book was being entirely rewritten, and all knew that a compendium of American geology was in preparation. The great task has been accomplished, the book is finished, and as friends are expressing their satisfaction and delight the press announces that his life work is done and we shall see him no more.

His first scientific paper was published in 1835, and his last book in 1895. Sixty years successfully devoted to the discovery and dissemination of scientific truths have made his a rare and eminently worthy life.

It was announced that the Council had elected Miss Grace E. Cooley, Mrs. William Barton Rogers, Messrs. W. L. W. Field, Garry de N. Hough, W. D. Jackson, W. T. Porter, and B. L. Robinson, Corporate Members, and Messrs. W. T. T. Dyer, A. C. L. G. Günther, George Henslow, Robert McLachlan, John Murray, Alfred Newton, E. B. Poulton, P. L. Sclater, S. H. Vines, and Henry Woodward, Corresponding Members.

The committee appointed to nominate officers for 1895–96 presented a report.

Prof. William Libbey, Jr., gave an account of his experiences during two months in Greenland.

The following paper was read: —

ON THE SOUTHWESTERN PART OF THE BOSTON BASIN.[1]

BY J. L. TILTON.

By Boston Basin is here meant that area of rocks of sedimentary origin that lies near Boston in a generally low surface surrounded by higher hills of granite and other igneous rocks.

In the fall of 1893 Mr. A. J. Collier found indications that the "Basin" was not closed at the sharp turn southwest of South Natick as indicated in Professor Crosby's map of the region, but from lack of time was unable to form any definite conclusions. Last fall the writer undertook to solve the relation between the rocks of aqueous origin with their accompanying igneous rocks and the surrounding granite.

A map of the area between South Natick, South Sherborn, and Charles River Village is here presented, on which the more important outcrops are marked, and a line drawn between areas of granite and areas of basin rock. Microscope slides have been prepared of many outcrops in the region studied, also photographs taken of conglomerate and granite exposures; but to avoid too great detail no descriptions of them are here included.

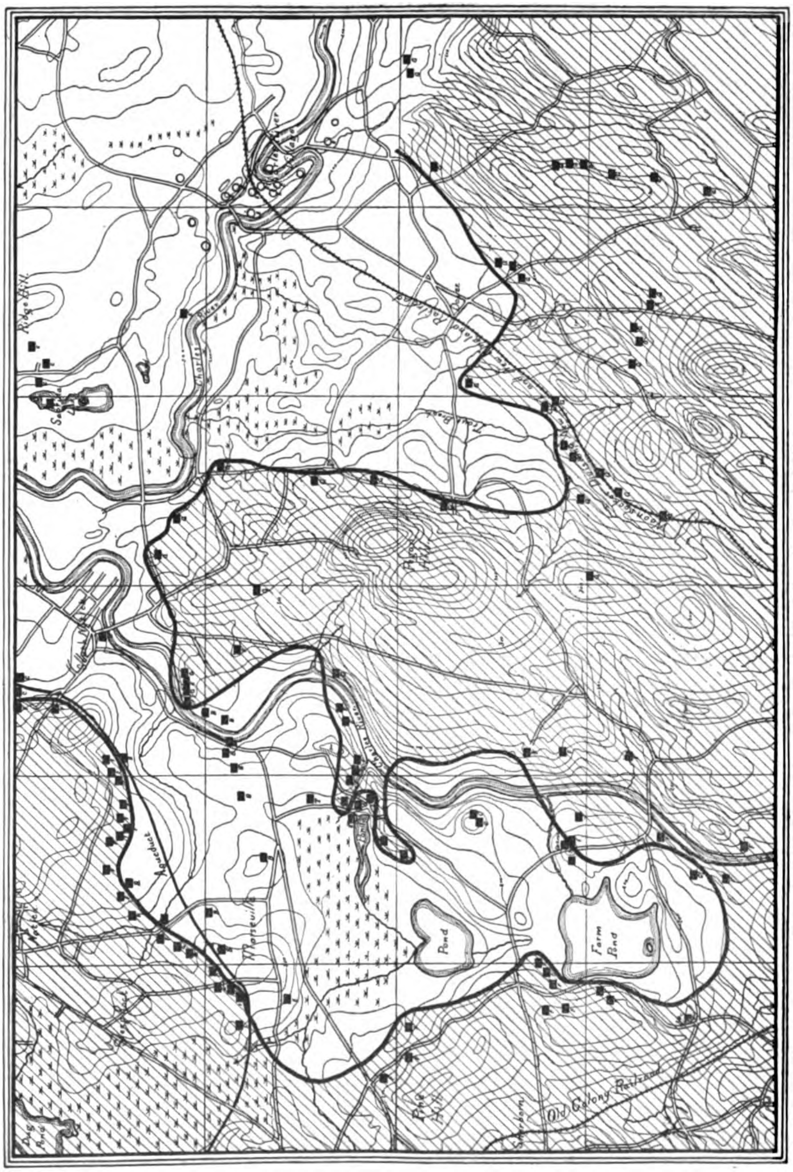
Brief Statement of the Boundary Line between Basin Area and Granite.

The line here drawn traces the outline of the granite area. It passes southwest from South Natick around Morseville, southward along the western side of Farm Pond, returning northward near Charles River, though a mile and a half above South Natick it projects westward a short distance. At South Natick it turns eastward and then southward, forming a large curve around Pegan Hill. It then turns eastward again, passing south of Dover toward Charles River Village.

[1] The writer wishes to acknowledge the assistance of Mr. L. S. Griswold of Harvard University, under whose direction the field work necessary to this paper was undertaken; also the assistance of Prof. J. E. Wolff and Mr. C. L. Whittle, to whose examination the microscope slides have been subjected.

THE SOUTHWESTERN PART OF THE BOSTON BASIN.

J. L. Tilton, December, 1894.



Scale, 1 in., 1 mile. General Dip and Strike of Pressure Planes. Granite. Felsite. Felsite, tuffaceous. Conglomerate. Breccia. O Eruptive Rock, Relation not determined.

General Character of the Rocks.

The rock in the general area surrounding this part of the basin is a hornblende granite, but close to the basin area the rock is generally a felsite.

Within the basin one rock is a conglomerate, the pebbles of which are quartz, subangular in shape, the larger ones about six inches long. With these quartz pebbles may be found a few granite pebbles, and, now and then, pebbles of diabase or dark felsite. The localities where this conglomerate is to be found are four in number: at Sabrina Lake, north of South Natick, northeast of Farm Pond in a large hill, and southeast of Farm Pond in a less conspicuous ledge.

The conglomerate outcrops close to Sabrina Lake are coarse as above described; but in the outcrops found a little to the eastward the conglomerate rapidly becomes much finer in composition, indicating a deposit a little further from shore.

There seems to be a transition from the conglomerate near Sabrina Lake through that north of South Natick to the volcanic breccia near Morseville.

A second rock in the basin area is an arkose rock found east of Farm Pond. The irregular angular granite fragments of which this rock is composed are not to be distinguished without a microscope.

The third rock is a volcanic breccia extending east and west through South Natick.

Discussions of Special Parts of the Boundary between Granite and Basin Rocks.

Proceeding from South Natick in a southwesterly direction, the volcanic breccia first claims attention. It extends in a curved line west and southwest to half a mile west of Morseville. It lies adjacent to the conglomerate northwest of South Natick, and north of Morseville. It also lies next to the granite south of South Natick.

One outcrop half a mile southeast of Morseville deserves special attention, as in this vicinity the breccia appears tufaceous.

There seems little reason to doubt that this rock is to be classed with the basin rocks. It is similar to other rocks to be found in various parts of the basin, and forms less conspicuous hills, as in the basin area generally, in contrast to the higher and more rugged hills of the surrounding granite area.

The second region requiring special attention lies just northwest of Farm Pond. Here the outcrops are the exposed parts of a ledge extending in a northeasterly direction for a quarter of a mile. The exposed rocks have suffered so much metamorphism that their exact derivation is not ascertained with certainty. They may have come from felsite arkose or from felsite breccia, thus may be either of a sedimentary origin or the dike equivalent of a granite.

A mile to the northeast, in the direction of the strike of one set of pressure-planes, a ledge similar in character to that just mentioned juts out from a granite area and extends southwestward toward the first mentioned ledge. Between these two ledges there is, toward the north, a large swamp, and toward the south, hills of drift (kame); but no outcrop of a rock that is undoubtedly of sedimentary origin. Yet, to the southeast of this line lie two ledges of conglomerate: one northeast of Farm Pond, near the river, the other southeast of Farm Pond, also near the river. Northeast of the latter is a line of angular conglomerate boulders for a quarter of a mile, though in no place is the face of a ledge to be discerned among them. These two ledges and a small area of clastic rock east of Farm Pond, form, with the outcrop of breccias near Morseville and South Natick, a broken line extending between granite areas toward the conglomerate north and northeast of South Natick. If the rocks north of Farm Pond were of undoubted clastic origin, this narrow area would stand connected with the breccias near Morseville; but the rock may be of igneous origin, in fact is better so explained not only in its microscopic structure, but also in its relation to the granite lying west.

No contact is to be discerned between the breccia and the granite, at least in this part of the line. Even if there were, it is not likely the contact would indicate the general position of the dividing line; but in other parts of the basin where contacts

between the basin rocks and the granite are found, the contacts lie near the granite highlands bordering the basin, and not at a distance inward toward the basin. It seems desirable, then, that where the exact position is not determined by the nature of the outcrops, the line should be drawn near the granite rather than along the nearest basin rock, or half way between the outcrops of the granite and basin rock. If this criterion be followed, the line must be drawn southward, including the Farm Pond outcrops of conglomerate as a part of the general basin area, rather than across from ledge to ledge north of Farm Pond, leaving these southern conglomerates in a small isolated basin.

The outcrop just south of the bridge over Charles River east of Farm Pond is not very conspicuous, but as the pressure-planes conform to the general direction of such planes, and the slightly raised extent of ground beneath the outcrops seems to indicate an underlying ledge, this locality is included in the granite area.

Along the river near by to South Natick, the granite forms an almost continuous irregular slope on the eastern side of the river; but immediately east of Farm Pond are a few outcrops near the road. The northern one of those east of the road is an arkose rock; the one a little to the south, a felsite. These rocks are so similar in their composition and appearance on weathering that no marked line of contact is visible; but because of the difference in their microscopic character, the line between the basin and the granite is judged to lie across this ledge.

Turning now from these evidences that the Boston Basin extends from South Natick to south of Farm Pond, let us consider briefly the conditions that exist east of South Natick in the large valley north of Dover.

As in the preceding description the line separating the basin area from the surrounding granite has been drawn along the outcrops of granite, so, from east of South Natick to near Charles River Village, the course of the line must be decided on the same general principle.

On the west side of the valley are the granite heights of Pegan Hill, from which two extensions run eastward into the valley. These extensions present a low rounded appearance as if deter-

mined by the presence of an underlying ledge. On the surface of each are numerous angular boulders, and one or two surfaces much like the rounded surfaces of an underlying ledge with pressure-planes extending in the general direction of pressure-planes found in ledges to the west. Between these two projections are a few rounded faces, apparently of a north and south cliff extending along the side of the hill close to the road.

In the swamp farther south is a somewhat large outcrop; and eastward nearer Dover, another place which, like those extending eastward from Pegan Hill, presents evidence of an underlying ledge.

Half a mile southeast of Dover other outcrops appear extending northeast toward another outcrop of granite half way to Charles River Village.

In the broad valley thus marked out, no outcrop is to be found as far as the igneous outcrop half a mile southeast of Sabrina Lake.

If, then, in locating the dividing line, we follow the principle previously noted, that where the dividing line is observed it lies near the granite highlands surrounding the Basin rather than in the Basin itself, we must here draw that line along the base of Pegan Hill to the west, thence in a wide curve south of Dover station toward Charles River Village. It is not intended to consider whether the line from this latter point should turn eastward or northward, since in both those directions the region lies beyond the area under consideration.

Annual Meeting, May 1, 1895.

President W. N. Niles in the chair. Forty-four persons present.

The following reports were presented: —

Report of the Curator, Alpheus Hyatt.

Last year special attention was called to the scientific investigations of Professor Crosby in the department of geology, and to the need of keeping up and providing for such a class of work,

if we desired to do our part in the history of science in New England. We are essentially a local society and ought to strive to do a large share of the local work of investigation. For the year past this Society has paid one of its salaries to this investigator and permitted him to count his purely scientific work in the field and in this building as a return for the money paid him. The amount expended has been very small and the returns, as will be seen by the text of this report, large. So far as I know, however, this Society is the first institution of its class in this country to grant a salary, even though it be a small one, for investigation.

This is one of the legitimate and direct results of our plan of organization. It is natural and entirely appropriate in a scientific sense, that, when departments are practically finished, those in charge of them should, if they still desire to remain with us and continue their work, take up corresponding departments of investigation in the natural history of our own region and conduct these for the exploration and exposition of our flora and fauna, as Professor Crosby has done in his work upon the geology of eastern Massachusetts.

I wish I could feel confident that in the years to come there would be a salaried investigator in every department of this museum, working as Professor Crosby now does in geology. My only remaining desire in that case would be, that they might be paid in proportion to their deserts and not as now in proportion to our limited income.

The first duty of an institution like ours is to provide for the safe keeping of the collections committed to its care and to exhibit them in proper shape for the instruction of the public. Its income may be, as ours at present is, hardly sufficient for these practical purposes, but if it has no higher aim its progress will necessarily stop with the final reports on each department and its museum will speedily fall far behind the perpetually progressing standards of other institutions.

If, on the other hand, it aims to foster and cultivate investigations, which are appropriate and which naturally follow after the practical work of caring for and exhibiting its collections is either partially or wholly completed in the different departments,

it may pass by degrees to this higher level of occupation and possibly finally make investigation its chief object. The entire museum will reflect such a spirit as this, and it may be safely asserted that its future will be better assured than by any policy of a more practical nature, which simply aims at the so-called completion of departments.

The Curator also desires to call attention to the crowded condition of the museum. There is not room enough for the guide to work effectively on the main hall floor. The entire center of this floor is crowded by the cases containing the mammals donated by the Boston Museum. We have finally got to a place in our history when it has become impossible to make farther progress without either adding to the building or flooring over the main hall. This latter plan would involve the least expense, and would enable us to accommodate the collection of mammals and unite and exhibit our entire New England collection which is now scattered, each department of the museum having its own New England collection.

The museum has been visited on days when the public is not admitted by 12 teachers and 206 pupils, representing 15 schools.

Teaching in the Museum.

The work in this department was continued uninterruptedly by Mr. A. W. Grabau on Wednesdays and Saturdays for the remainder of the month of May after the annual meeting and in June (with the exception of June 17, a public holiday). The teaching is always omitted during July and August, but it was resumed again on the second public day in September and continued without interruption through September, October, and November. December, January, February, and March were necessarily omitted. The Museum not being heated, the weather is too cold to allow the work to be continued through the winter. The lecturing was resumed on the first public day of April, 1895, and has been carried on since. The attendance has been good throughout, and the interest of the visitors has been steadily increasing, many of them coming several times to hear the same talk. Two cases are known to me where

people came from out of town on several successive Saturdays to get instruction. Three persons, interested in the subject of geology and general natural history, came almost every public day during the season of 1894, and two of these have continued the study of geology outside. The following is an approximate record of attendance: —

1894, May, 222; June, 419; September, 251; October, 379; November, 233. Total, 1894, 1504.

Beginning April, 1895, a new plan was inaugurated; namely, that of giving regular lectures on stated subjects and at stated hours. These lectures are delivered in the lecture hall of the Society where illustrations by diagrams and blackboard drawings are available and where also the audience can be seated and take notes if they desire to do so. The first lecture was given Saturday, April 13, at 11 A. M., and was attended by 80 or more persons, most of them teachers. After the lecture, they were taken to the cases where the specimens illustrating the special subject under discussion were pointed out and explained, and an opportunity was offered for discussion, in which a number took part. Altogether seven lectures have been given with a total attendance of about 250. The Saturday morning lectures are the best attended, and these were announced by circulars sent to the schools of Boston and to the papers. As an example of the appreciation of these lectures by the public, it may be stated that a teacher from one of the towns in the neighborhood of Boston said to Mr. Grabau that his explanations had given her more information than whole days of previous visits to the museum. The continuance of this department is at present entirely dependent upon the interest and generosity of a lady who is a member of this Society.

The following copy of the circular sent out will give some idea of the object and scope of the public lectures.

"A course of popular lectures will be given by Mr. A. W. Grabau on consecutive Saturday mornings at 11 o'clock, in the lecture hall of the Society. The course will begin with four popular lectures on geology, the first to be given Saturday morning, April 13, 1895. The subjects of the first four lectures are:

1. April 13. The work done by the ocean.
2. April 20. The work done by rivers and glaciers.
3. April 27. The work done by atmospheric and organic agencies.
4. May 4. The work done by igneous agencies.

Following these will be lectures on various branches of zoölogy.

These lectures are especially designed to explain the collections in the museum, and after every lecture some time will be spent in the examination of the specimens. Thus teachers intending to make use of these collections in their work will have an opportunity to become acquainted with them. A great advantage over previous methods of instruction lies in the fact that visitors will have a series of lectures covering progressively the principal portions of the collections."

Dynamical Zoology.

The Curator has expended considerable time upon the genus Achatinella in working up and describing the species and in trying to obtain suitable materials to fill gaps in the series.

Geology.

During the summer and fall Prof. W. O. Crosby devoted much time to field work in the Blue Hill area. Early in the season, and in a part of the Hills not previously examined in detail, he found an important clue to the relations of the granites and the felsites. This discovery indicates, in general terms, that the hills are laccolitic or batholitic masses of granite in the midst of the Cambrian slate. The felsites occur chiefly as a contact zone between the granite and slate, and partly as great dikes and surface flows. The chief object of the field work has been to test this new idea and to determine the outlines of the various batholites.

Feeling the great importance of having the igneous rocks of this area studied microscopically, Professor Crosby made an arrangement with Mr. Theo. G. White of Columbia college, New York City, to co-operate with him in this part of the work,

and this gentleman has taken to New York nearly all the material required for this investigation. This co-operation puts the work on a more satisfactory basis, and relieves Professor Crosby of the most irksome part of it, for which also he feels that he has no qualifications.

Professor Crosby has also made a satisfactory arrangement for co-operation with the Metropolitan Park Commissioners in the preparation of a topographic map of the Metropolitan district, which will serve as a suitable basis for the representation of the geology. In following out this line of investigation the same gentleman has prepared a chapter entitled "Notes on the geology of the Reservation," which has been published in the "Annual Report of the Commissioners for 1895." In consideration of his services in giving them this account of the geology of the Reservations, the Commissioners incorporated such topograpic features in their new map of these localities as were necessary to adapt it more perfectly to our geological work. Besides the extra office work which this involved, they also appropriated $350 to cover the cost of field work to collect the additional data required.

This arrangement will very greatly expedite the geological work on the Boston Basin, in so far as it will save considerable outlay in time and money devoted to topography and to the construction of maps.

Estimates have been obtained for the engraving and printing of the second sheet of the general map of the Boston Basin; and a friend of science has generously donated a sum sufficient to defray the cost of this sheet, which embraces the area to be covered by parts 3 and 4. The third part of the work has been temporarily delayed by Professor Crosby's co-operation with the Park Commissioners, and by the new discoveries that have been mentioned above, and by the necessity of waiting for Mr. White to finish his microscopic examinations of the rocks.

A new vista has also opened in the history of the surface or glacial geology in this region. It has become evident that about all of the sandplains of the South Shore district may be regarded as deltas formed by glacial rivers at different stages in the evolution of a glacial lake which stretched along the front of the ice-

sheet for a dozen miles, from Cohasset to the Blue Hills. It is proposed by Professor Crosby to name this ancient lake in honor of a gentleman who has done much work on the natural history, and especially the glacial geology, of that district. The name proposed is Lake Bouvé.

Professor Crosby, with the active assistance of Mr. Grabau, is now engaged in tracing out the shores, islands, and deltas of this lake, which he is confident will hereafter be generally recognized as one of the most important and interesting features in the geology of the South Shore.

Mineralogy.

The revision of this collection has been contemplated for five years past, owing to the changes in materials that have taken place since the collection was finally reported upon in May, 1883. Professor Crosby has this year reviewed the entire collection and has incorporated all the additions that have been accumulating in the last ten years. It was fortunate that he was able to do this without materially disturbing the classification or making any serious changes in the text of the Guide published in 1886.

Botany.

The Curator has from time to time had the satisfaction of making comprehensive reports upon different departments which show the entire possessions of the Society in each department. These often represent a number of years of more or less patient labor which cannot be appreciated by any one who has not passed through similar experiences. Miss Carter's work under the superintendence of Mr. John Cummings is first noticed in the report of the Curator for May, 1874, and since that time Mr. Cummings and this able assistant have contributed their personal care and labor to this department, which with the insects and birds is one of the three most difficult collections to keep safely and in good condition.

Through the generous interest of Mr. Cummings, his assistant has not only labored on the botanical collection, but she has

often for months at a time been permitted to give her services to the labeling and mounting of other collections, especially in the paleontological, mineralogical, and geological rooms, and the Society owes much of the fine appearance of those collections to her labors.

The revision of the specimens of the botanical collection has been continued through all of these years, and our reports show the steadiness and large amount of work done in each year. It is, therefore, a matter of serious congratulation that the general revision has been completed and that in this report we are able to present a summary of the entire herbarium belonging to the Society.

The general collection contains 39,357 specimens, representing 204 orders, 4,076 genera, 21,515 species.

The New England collection contains 4,531 specimens, representing 125 orders, 797 genera, 2,187 species.

The John A. Lowell collection contains 17,783 specimens, representing 210 orders, 2,322 genera, 8,318 species.

The C. J. Sprague collection of lichens contains 2,638 specimens, representing 79 genera, 694 species.

The Seymour and Earle collection of economic fungi contains 490 specimens, representing 73 genera, 273 species.

Sum total of herbarium, 64,799 specimens.

Our entire herbarium is now accurately named, and in some collections there is a large proportion of authentic names given by specialists.

The duplicates will be reported upon next year.

The poisoning of the plants is about one half completed.

About two thirds of the specimens in the Lowell herbarium are not yet provided with special labels, designating the collection to which they belong. The revision and copying of the catalogue has been begun but is not included in this report.

The preparation of suitable specimens that are needed for the exhibition collection also remains to be done.

The following accessions are hereby acknowledged: —

Miss C. H. Clarke, 9 specimens New England Algae.

Mrs. Gunning, 35 specimens Florida Algae, 1 specimen Manzanita Burl.

Miss Isabel L. Johnson, 1 specimen Pinus pinea.

Mr. T. T. Bouvé, 5 specimens New England collection.

Mr. Henry Brooks, 17 specimens sections of wood.

Mr. Geo. F. Curtiss, 6 specimens Jamaica ferns, also 1 specimen Uniola paniculata.

Mr. E. W. Roper, 40 specimens Jamaica ferns.

Mr. B. P. Mann, 14 specimens, mostly lichens.

Twenty-eight persons have been allowed the use of the herbarium, and fully as much time devoted to this work as during the preceding year.

Synoptic Collection.

Miss J. M. Arms, the assistant placed in charge of this collection during the past official year, has accomplished considerable toward the completion of this important department. Sponges have been rearranged and illustrations hung in place; specimens of Hydrozoa and illustrations have been prepared and drawn by Miss Martin; the text of the guide for this part of the collection has been revised and enlarged; series of specimens of starfishes and Pelecypoda have been picked out and prepared for exhibition; and considerable portions of the text of the guide for Echinodermata and Pelecypoda have been written. Work has also been done upon the preparations showing homologies of the Arachnozoa, and the descriptive text for these preparations has been written. A series of brachiopods illustrating the evolution of the more characteristic forms of this important group has been selected. A number of specimens of Gasteropoda and Cephalopoda have also been selected.

Paleontology.

Professor Crosby and Miss Ballard have collected and studied the drift fossils, and published in the American journal of science, vol. 48, December, 1894, a paper, "Distribution and probable age of the fossil shells in the drumlins of the Boston Basin," embodying the results of their work. The collection made by them has been placed in a case so that it can be consulted.

Professor Crosby and Miss Ballard have also collected the recent fossils from the Charles River flats now being excavated on the easterly side of Harvard Bridge. Between thirty and fifty species were found, and a few of these had not been mentioned in Upham's "Recent fossils of the Harbor and Back Bay, Boston" (Proc. Bost. soc. nat. hist., vol. 25, 1891).

Miss E. D. Boardman has continued her labor upon the Curator's collection of Quaternary fossils of Planorbidae from Lawler's Lake, and has about finished the preliminary and rather uninteresting work of sifting the samples of earth and clay from the different layers and picking out the shells.

Miss Ballard has mounted and catalogued all the new materials for the Lower Silurian and finished the revision of the exhibition collection for the Trenton and Hudson River groups. She has worked over all the materials of the Medina, Clinton, Niagara, including the Guelph, Salina, and Lower Helderberg groups, thus completing the Upper Silurian. This includes the mounting of selected specimens for exhibition, the arrangement of the stored materials, and the picking out of duplicates. Similar work on the Oriskany fossils has also been completed. The same assistant has also worked over the Hyatt collection through the Lower Silurian, picked out materials suitable for exhibition, and incorporated the remainder with our other collections.

Porifera.

Considerable work has been done upon this collection by the Curator assisted by Mrs. Flint, in securing the safety of the material with rubber corks and proper glass-stoppered bottles, and in completing the arrangement of the stored specimens. All of the stored materials underneath the exhibition cases have been reviewed, cleaned, and catalogued by Mrs. Flint.

Actinozoa: Echinodermata.

The stored specimens have been inspected and catalogued by Mrs. Flint.

Mollusca.

Mr. Edward W. Roper having expressed a willingness to assist the Society by working upon this collection, the Curator asked him to take charge of the department. This gentleman accordingly began the classification, arrangement, and incorporation of the Mayo collection of land shells, and succeeded in doing in a short time a large amount of work in this direction. All the Zonitidae and Helicidae treated in Tryon's Manual of conchology, through Polygyra, have been assorted and labeled, with the exception of a few shells without name or locality, and these are all now incorporated with the Society's collection.

The remainder of the Mayo collection of Helicidae has also been labeled and arranged, but is not yet united with the Society's collection. The shells of the genera Cylindrella, Clausilia, Pupa, Helicina, and most of the Bulimi, have been assorted into genera, but the labeling has not been completed.

It is a serious loss to the Society, as well as a matter of deep regret to his friends, that Mr. Roper's state of health is such as to make it essential for him to seek a milder climate and give up this work which he had begun and conducted so rapidly and successfully and in which he was much interested.

The Curator has spent most of his time, not occupied by routine duties, in the classification and arrangement of the rich collection of Pectenidae in the Society's possession, redescribing the genera and grouping the forms in accordance with the law of bioplastology. A few specimens of rare species have been added by purchase to this part of the collection. A fine suite of the shells of Pteropoda has been purchased, and Miss Martin has prepared a series of colored drawings of the animals to accompany these shells.

Worms.

The specimens in this collection have been catalogued by Miss Martin. A small but interesting collection of recent shells of Brachiopoda has been added by purchase to this department.

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Laboratory.

The room of this department has been used as in previous years by three classes from the Boston University and by two classes of the Teachers' School of Science. The use of this room was also granted to an advanced class of the Normal School which has occupied it for finishing the course begun in May, 1894, and another similar course has been begun in the same room but is not yet finished.

Considerable work has been done by Mrs. Flint in numbering the specimens of the collection, in preparation for a new catalogue, the old one having become useless on account of the numerous changes in materials.

Mr. Grabau has done some work on this collection and has donated a few specimens of Columnaria and Brachiopoda.

Teachers' School of Science.

The temporary connection with the students of the Normal School has been continued this year. The course given by Miss J. M. Arms in the laboratory of the Society, and referred to in the last annual report, was successfully finished in June, 1894. It consisted of lessons of two hours each upon the common types of echinoderms, mollusks, crustaceans, and insects, given with special reference to the efficient teaching of these subjects in elementary schools. Miss Arms's great experience and ability in this direction are well known, and it is unnecessary to add that the lessons were highly appreciated by the officers of the Normal School and by her pupils.

A similar course has been given this year in February and March, consisting of lessons of two hours each, and has been equally successful. Field lessons are also contemplated in connection with this course to be given when the season is suitable.

The ladies of the Woman's Education Association were appealed to by Miss Dora Williams of the Normal School and generously responded, paying for the services of the teacher in the last series of lessons, the first series having been given gratuitously by Miss Arms.

The course gratuitously given by Prof. W. H. Niles and Mr. G. H. Barton to the students of the Normal School, and alluded to in the last annual report, was finished. The class consisted of 13 members, and four lessons on geology were given in the field during May and June, 1894.

This year the same class has been continued under the charge of Mr. Barton with a membership of 11 persons. A course of 10 lessons has been arranged to be given in the immediate vicinity of Boston at points where the elements of geological field work can be easily studied and presented plainly to a class. Four lessons of this course have already been given. The teacher in this course has also been paid by the Woman's Education Association.

Professor Crosby proposed in connection with his work upon the geology of the Boston Basin to give a course of lessons in the field which would make his published works more useful to persons dwelling within the limits of those parts of that region which have already been described and mapped. This attempt to make the results of original investigation in geology of immediate interest and of educational value to the residents within the natural and geological limits of the Boston Basin was not expected to attract large audiences. The novelty of the undertaking, and the necessarily limited area from which the audience was to be drawn, tended to reduce the numbers of pupils. Nevertheless it was felt that even if ten persons could be induced to subscribe to and attend the course, a very important step would have been successfully taken towards the diffusion of a knowledge of geology in the districts gone over.

In pursuance of this plan two courses of field lessons (14 lessons in all) on the geology of Nantasket and Cohasset were given by Professor Crosby. Each course was attended by about twenty persons, or forty in all. This number was satisfactory, considering that our anticipations were not sanguine, that they were paid courses and in a somewhat inconvenient locality, where the incidental expenses were almost equal to the fee for the lessons.

In connection with the field and laboratory classes in the geological courses, an excursion was made during the summer of 1894 under the charge of Mr. Barton to the principal mineral and

mining localities of Nova Scotia. Such noted places as the vicinity of Parrsboro', Cape Blomidon, Winsor, and Halifax, the coal mines at the South Joggins, the iron mines at Londonderry, and the gold mines at Montague were visited. The party, consisting of 20 persons, left Boston on July 2 and returned on July 22.

An excursion is planned for the coming summer to some localities of geological and mineralogical interest in western Massachusetts, visiting among other points the corundum mines at Chester, kaolin deposits at Blanford, iron mines in West Stockbridge, sand work at Cheshire, limestone quarries in Adams, North Adams, etc., Hoosac tunnel, Shelburne Falls, Mt. Grace in Warwick, Turner's Falls reptile tracks, etc.

In consequence of the hard times, the Trustee of the Lowell institute did not continue the support of the course to the second section of the class in mineralogy which was begun last year, and it became necessary to provide for this section in some other way. This was accomplished by a voluntary subscription from the whole class. One half of the class voluntarily fined themselves to the extent of one half the fee charged, in order that the other half might enjoy the same privileges as themselves. This remarkably generous and praiseworthy action was wholly suggested and carried through privately, by the teachers themselves, after it was known that a fee would be charged, the money being collected and paid in also by their authorized collectors. The second section of Mr. Barton's class in mineralogy, alluded to below, therefore has to be mentioned here, and does not belong among the Lowell Free Courses.

The Lowell Free Courses in the Teachers' School of Science have been as follows: —

The field course in geology by Mr. Barton referred to in the last annual report as "the spring course" and as having begun on April 28, 1894, with an attendance of 75 members, was successfully carried out. The class made ten trips. Most of these were directed to points of local geological interest, but there were some of wider scope which were made to Rockport, Clinton, and Mt. Holyoke. The last excursion occupied three days. The average attendance in this course was 38.2.

The field course in the autumn, also conducted by Mr. Barton, consisted of ten trips in the field. Excursions, occupying two days each, were made to the Hoosac Tunnel, Mt. Greylock, and Newport. The average attendance was 38.5.

The spring course in field work by Mr. Barton has been begun and will be reported upon in the next annual report. A full account of the methods of work pursued in these field excursions was given in the last annual report and need not be repeated here.

A class in mineralogy under Mr. Barton began on December 8, 1894, and ended on April 13, 1895, having had 17 lessons of two hours each. The number of applications for this course was very large and in consequence of this a special circular was issued requesting each person who was granted a ticket of admission to sign an agreement to remain a member of the class during the complete four years' course in geology, mineralogy being the first year of this course. This agreement was signed by about 115 persons, and tickets were issued to 112 persons. Special arrangements were made with the Massachusetts Institute of Technology for the accommodation of this large number in two divisions of 56 each.

For the first five weeks both divisions met in the lecture hall of the Society, then 11 exercises were held with each division in Room 12 of the Rogers Building of the Institute, and finally the last exercise was held in the original hall. The average attendance for the course was 92.94. The second division has been mentioned above as paid for by the teachers themselves and was therefore included under the general heading of the Teachers' School of Science.

The method of instruction was as follows: The larger number of the class had little or no knowledge of chemistry. In consequence of this the first lesson was devoted to an exposition of the fundamental principles of that science and of the principal facts relating especially to its application to mineralogy.

The next four lessons were devoted to a study of the physical properties of minerals, especial stress being laid upon crystallography. After this, all but the last lesson were spent upon the study of the specimens themselves, in which each member was

required to become familiar with about 200 of the commonest species of minerals and a much larger number of varieties. The final lesson of the course was devoted to a summing up of the principles of the science and a statement of its natural relations. Examinations comprising all of the subjects that had already been studied formed an important part of work at each exercise. These consisted of questions and of the identification of specimens with a statement of their composition and place in the classification. No final examination was held, but in its place an essay upon the subject was required to be handed in before the beginning of the course in lithology next winter.

Dr. Robert C. Greenleaf, with his usual completeness and success, gave a course upon fossil plants in continuation and conclusion of the series of lessons begun four years ago.

The first year of this series was spent upon structural, physiological, and morphological botany, the second year upon a systematic study of phanerogams, and the third upon a similar review of the cryptogams.

Forty-three persons joined the class this year, and of these twenty-four were members of the previous year's class. There were fifteen exercises of two hours each, beginning, November 3, 1894, and ending, March 2, 1895, and a final examination on March 16. The exercises consisted of a brief written examination and a lecture followed by laboratory work. The average attendance was 31. Twenty-seven persons took the final examination, passing as follows: seventeen with honor, eight with credit, and two with pass marks. There were no failures and the general standard of the answers was exceptionally good.

The method of presentation of the subject was essentially that which has proved of value in previous years; viz., of using a considerable amount of laboratory material and of grouping varied facts synoptically about simple types explained in the lecture demonstration. The duplicate fossil specimens of the Society were freely used by this class, and one hundred and thirty-six specimens, including ninety determined species and their duplicates, were given out for study. Most of these were carefully figured by each member of the class. In addition to these specimens many others were shown on the lecture table.

Dr. Greenleaf asks me to express his thanks to Profs. W. H. Niles, W. O. Crosby, and Mr. G. H. Barton, for the use of materials from their laboratories; also to Miss Hetty O. Ballard and Mr. Amadeus W. Grabau for valuable assistance.

The series of special courses given by the Curator was continued. Nineteen lessons of two hours each were given, exclusive of the examination, beginning on November 3, 1894, and ending on March 30, 1895. The examination was held on April 13, 1895. The whole number of tickets issued was about forty, and the average attendance was thirty. This increase over last year was probably due to the subjects treated, insects and vertebrates, the study of these being more popular among teachers than that of the simpler forms of the animal kingdom. Fifteen persons took the examination, and the results were as gratifying as in previous years.

Report of the Secretary and Librarian, Samuel Henshaw.

Membership.

Twenty-two Corporate members have been elected by the Council; three have died, three have resigned, and six have been dropped for non-payment of dues.

In the death of Dr. Oliver Wendell Holmes the Society has lost one of its earliest members, one whose name has been upon the roll since April 6, 1831.

Ten Corresponding members have been elected; four have died.

Two of the most honored of our Honorary members, Prof. James Dwight Dana and Joseph Hyrtl, have died.

Mention of the death of Mrs. Augustus Hemenway, a patron of the Society, and at one time a generous supporter of the Teachers' School of Science, should have been made last year. Mrs. Hemenway died, March 6, 1894.

The present membership of the Society consists of 14 Honorary, 149 Corresponding, and 357 Corporate members, a total of 520. Until the number of our Corporate members equals the present total number of members, once a year is not too often to call the earnest attention of all solicitous for the welfare of the Society to the need of adding to our roll.

Meetings.

The usual fourteen meetings have been held, and it is gratifying to record an increase in interest as manifested by the attendance.

The average last year, 70 *plus* to a meeting, though the largest that had been recorded in any previous year, has been increased to 84 *plus*, the total attendance being 1,182.

The largest attendance at any one meeting was 284, the smallest 30; the largest last year was 247, the smallest 27.

Twenty-six communications have been made by twenty-six persons, and of these twenty-six speakers, twelve have favored the Society for the first time.

Eight papers have been presented by title.

Publications.

The publications distributed this year consist of (1) Mr. E. A. Burt's account of a North American Anthurus (19 pages, 2 plates), issued as the concluding number of the third volume of the Memoirs. (2) The indices, tables of contents, and title pages of the third and fourth volumes of the Memoirs. (3) Parts two and three, p. 153–392, of volume 26 of the Proceedings. (4) Part 2 of vol. 4 of the Occasional Papers, 110 pages, 3 maps, 3 plates, containing Professor Crosby's description of the geology of Hingham in his Geology of the Boston Basin.

In addition to the above more than 100 pages for the concluding part of volume 26 of the Proceedings are in type.

Library.

The additions to the library are as follows:—

	8vo.	4to.	Folio.	Total.
Volumes	369	69		438
Parts	1,866	323	1	2,190
Pamphlets	357	80	1	438
Maps, photographs, etc.				49
			Total,	3,115

The total 3,115 exceeds the number 3,069 recorded last year, which was larger than that of any previous year.

The library contains 21,960 volumes, 1,227 incomplete (including current) volumes, and 10,430 pamphlets.

New exchanges have been arranged with fourteen institutions as follows: Annaes de sciencias naturaes, Porto; Colorado college scientific society; Colorado scientific society, Denver; Department of zoology, Oxford; Field naturalists' club of Victoria, Melbourne; Michigan geological survey; National geographic society, Washington; Naturwissenschaftlicher verein des regierungsbezirks, Frankfurt am Oder; Revue des sciences naturelles de l'ouest, Paris; Royal Scottish geographical society; Trinidad field naturalists' club; United States bureau of ethnology; United States national museum; University of Wisconsin.

By purchase we have added five serials: Annals of British geology; Journal of the anthropological institution of Great Britain; Journal de micrographie; Maynard's Contributions to science; Revue générale de botanique.

The Society now exchanges its publications with 392 scientific societies and periodicals.

One thousand and fifty-eight books have been borrowed from the library by 125 persons, 336 books have been borrowed for use in the building, and the library has been consulted 634 times.

Six hundred and sixty-four volumes have been bound in 513 covers.

The list of 17 serials, 201 volumes, indexed this year is as follows: —

Archives de biologie.	12 vols.
La cellule.	10 vols.
Jenaische zeitschrift.	21 vols.
Journal de l'anatomie et de la physiologie.	1 vol.
Leipzig. K. sächsische Gesellschaft. Abhandlungen (natural history articles).	15 vols.
Marine biological laboratory lectures.	2 vols.
Natural history society of Wisconsin. Occasional papers.	2 vols.
Niederländisches archiv f. zoologie.	6 vols.
Palaeontographica.	18 vols.
Revue générale de botanique.	6 vols.
Royal society of Canada. Proceedings and transactions (natural history articles).	11 vols.

Schenk's Handbuch der botanik.	4 vols.
Wien. K. Akademie d. wissenschaften. Denkschriften (natural history articles).	58 vols.
Zoologisches institut. Arbeiten.	10 vols.
Würzburg. Zoologisch-zootomisches institut. Arbeiten.	10 vols.
Zoologische beiträge.	3 vols.
jahrbüche.	12 vols.

The total number indexed is 47 serials, 546 volumes; current volumes of serials indexed in previous years are indexed as received.

One of the basement rooms having been granted to the library, has been in part supplied with shelves and the books are already arranged there. When connected directly with the front library and entirely supplied with shelving this room will relieve overcrowding for a number of years.

Walker Prizes.

The Walker Prize Committee announced the following as the subjects for the annual award: —

(1) A study of the "Fall line" in New Jersey.

(2) A study of the Devonian formation of the Ohio basin.

(3) Relations of the order Plantaginaceae.

(4) Experimental investigations in morphology or embryology.

Three essays have been received, and the chairman of the Committee, Dr. Goodale, has, in accordance with the rules of the Council, informed me that the Committee unanimously agreed to award a prize of sixty dollars ($60) to the author of the essay on the Devonian formation of the Ohio basin, bearing the motto "Complet orientalem Devonia occidentalis," and a second prize of fifty dollars ($50) to the author of the essay on Variations in development of Limulus polyphemus, inscribed X. Y. Z.

The subjects announced for next year are: —

(1) A study of the area of schistose or foliated rocks in the eastern United States.

(2) A study of the development of river valleys in some considerable area of folded or faulted Appalachian structure in Pennsylvania, Virginia, or Tennessee.

(3) An experimental study of the effects of close-fertilization in the case of some plant of short cycle.

(4) Contributions to our knowledge of the general morphology or the general physiology of any animal, except man.

REPORT OF THE TREASURER, EDWARD T. BOUVÉ.

ANNUAL STATEMENT, MAY 1, 1894 TO MAY 1, 1895. BOSTON SOCIETY OF NATURAL HISTORY.

By cash received from Walker Prize and Special Expense Fund	$713.00
By cash received from Walker Grand Prize Fund	106.04
" " " " " Fund Income for General Expenses	676.00
By cash received from Walker Residuary Fund	386.66
" " " " Bulfinch St. Estate Fund	1,248 02
" " " " Courtis Fund	446.14
" " " " C. L. Flint Fund	236.46
" " " " J. W. Randall Fund	250.00
" " " " H. F. Wolcott Fund	498 84
" " " " S. P. Pratt Fund	545.64
" " " " Entomological Fund	19.94
" " " " Special Museum Fund	54 67
" " " " Annual Assessments	1,266.00
" " " " Admission Fees	90.00
" " " " " " to Museum	223.94
" " " " Library Fines	11.35
" " " " Sale of Publications	367.58
" " " " Rent of Lecture Room	10 00
" " " " Dividends and Income	4,331.04
" " " " Boston University	2,500.00
Total,	$13,981.32

By cash paid on account of Repairs	$169.58
" " " " " " Fuel	201.28
" " " " " " Gas	28.10
" " " " " " Insurance	163 50
" " " " " " " carried to Sinking Fund	297.37
By cash paid on account of General Expense	806.87
" " " " " " Profit and Loss repaid Sec'y amount stolen	27.40
By cash paid on account of Salaries and Wages	8,380.00
" " " " " " Walker Prize and Special Expense Fund	79.66
By cash paid on account of Laboratory materials	88.38
" " " " " " Pratt Fund Income: Conchological Books	10.00
By cash paid on account of Library	1,149.93
" " " " " " Publications	1,241 32
" " " " " " Museum	523.94
" " " " " " Special Museum Fund Investment	54.67
By cash paid on account of Entomological Fund: Invest.	19.94
" " transferred to Trustees Walker Prize and Grand Prize Funds	739.38
Total,	$13,981.32

By cash received from Augustus Lowell, Trustee for the Teachers' School of Science	$2,450.00
Balance from April 30, 1894	271.03
Total,	$2,721.03

By cash paid for Lectures and Supplies	$2,313.89
Balance to new account	407.14
Total,	$2,721.03

The Auditing Committee reported that the Treasurer's cash account was correct, that they had examined the vouchers in the Treasurer's hands, and that the securities in charge of the Trustees agreed with the ledger accounts.

It was voted to accept and place on file the several reports.

On opening the envelopes accompanying the Walker Prize essays, Prof. E. W. Claypole was announced as the author of the paper on the Devonian formation of the Ohio Basin to whom the committee awarded the first prize, and Prof. William Patten the author of Variations in development of Limulus polyphemus to whom the second prize was awarded.

The Society proceeded to ballot for officers for 1895–96.

Messrs. R. E. Dodge and G. H. Barton were appointed a committee to collect and count the votes. They reported twenty-four ballots cast, a majority being for the candidates nominated.

OFFICERS FOR 1895-96.

The (*) indicates election at this meeting.

PRESIDENT,

*WILLIAM H. NILES.

VICE-PRESIDENTS,

*NATHANIEL S. SHALER. *WILLIAM G. FARLOW.
*CHARLES P. BOWDITCH.

CURATOR,

*ALPHEUS HYATT.

SECRETARY,

*SAMUEL HENSHAW.

TREASURER,

*EDWARD T. BOUVÉ.

LIBRARIAN,

*SAMUEL HENSHAW.

COUNCILLORS FOR THREE YEARS,

*Hermon C. Bumpus.
*Charles B. Davenport.
*William A. Jeffries.
*George G. Kennedy.
*Augustus Lowell.
*Miss Susannah Minns.
*Thomas A. Watson.
*Samuel Wells.

COUNCILLORS FOR TWO YEARS,

S. L. ABBOT.
WILLIAM S. BRYANT.
WILLIAM M. DAVIS.
J. WALTER FEWKES.
EDWARD G. GARDINER.
HENRY W. HAYNES.
MISS CATHARINE I. IRELAND.
BENJAMIN JOY JEFFRIES.

COUNCILLORS FOR ONE YEAR,

GEORGE H. BARTON.
WILLIAM BREWSTER.
MISS CORA H. CLARKE.
ROBERT T. JACKSON.
NATHANIEL T. KIDDER.
EDWARD S. MORSE.
A. LAWRENCE ROTCH.
WILLIAM T. SEDGWICK.

COUNCILLORS *ex-officiis*,

THOMAS T. BOUVÉ.
JOHN CUMMINGS.
GEORGE L. GOODALE.
F. W. PUTNAM.
SAMUEL H. SCUDDER.

GENERAL MEETING, MAY 15, 1895.

President W. H. NILES in the chair. Thirty persons present.

Prof. Thomas Dwight gave an account of the anatomy of the chimpanzee "Gumbo." See Memoirs Boston society of natural history, vol. 5, no. 2.

Prof. N. S. Shaler read a paper on the conditions of escape of gases from the interior of the earth.

The following papers were read:—

NOTES ON NORTH AMERICAN MAMMALS.

BY OUTRAM BANGS.

THE SYNONYMY OF THE EASTERN SKUNK, MEPHITIS MEPHITICA (SHAW), WITH THE DESCRIPTION OF A NEW SUBSPECIES FROM FLORIDA.

There has always been some doubt in my mind whether Linnaeus's name *Viverra memphitis*[1] in the tenth edition of the Systema naturae should not be used for our eastern skunk; and in order to settle this I have been at some pains in looking up the early history of this beautiful but ill-smelling little animal.

Linnaeus's description is wholly inadequate, but he refers to the three following authors all of whom I have carefully read:—

1. Hernandez, Mexico, 332.

[1] Undoubtedly a typographical error for *mephitis*.

2. Seba, Museum, vol. 1, p. 68, pl. 42.
3. Ray, Quad., p. 181.

Hernandez gives a figure of an animal with a banded or annulated tail that he calls yzquiepatl, and states the color to be that of burnt maize; he then expatiates for nearly a page on the awful odor of the animal, which is worse than anything in nature, and which is due to a yellow fluid that is ejected as a means of defence. He says further that there are two additional kinds of this little fox, one distinguished by many white stripes which he calls yzquiepatl no. 2; the other by one white stripe on each side reaching to the end of the tail. This he calls conepatl.

It seems to me that Hernandez is quite clear. His yzquiepatl is probably the Nasua, yzquiepatl no. 2 is Spilogale, and conepatl either Conepatus or Mephitis. The only mistake he made was in attributing the peculiar means of defence of the skunks to the Nasua as well.

Seba gives a long and accurate account of the Nasua, and the Nasua alone, principally taken from one he kept alive for a whole summer and which was sent to him from Surinamo. There can be no doubt of either his plate or description. Among other things he mentions the habit of rooting in the ground with the snout like a pig.

Ray simply quotes from Hernandez.

By a strict application of the rules of nomenclature it seems that Linnaeus's specific name of *mephitis* might fall to the lot of one of the Nasuas. Schrieber in Säugethiere, 1778, under the name *Viverra mephitis* Linné describes and figures (Plate 121) an animal that leaves no doubt as to what he had; not only was it the eastern skunk, but his remark that the tail was half the length of the head and body ties his name down to the northeastern skunk.[1] Unfortunately, he had no right to use the Linnaean name of a Mexican animal, whether determinable or not, for a North American skunk, and we must pass on to the next name proposed which is *Viverra mephitica* Shaw, Museum Leverianum, 1792.

Shaw figures an animal, undoubtedly a skunk, of the genus Mephitis and gives a very brief description but with no meas-

[1] The true *Mephitis mephitica* (Shaw) of this paper occupying the Canadian and Hudsonian zones of the east.

urements or proportions, simply stating the animal to be North American (although his artist drew it wandering about under huge palm trees). He refers to Buffon and Pennant, Hist. quad., but these authors are so vague and confused on this subject, that they are of little value.

My researches in this matter do not alter the name which has been in common use for a long time for our eastern skunk, but they seem worth mentioning as placing Shaw's name on a firm basis. I am aware that many mammalogists had misgivings as to its right to stand.

If I have not overlooked some obscure earlier name, the skunk of northeastern North America must still be *Mephitis mephitica* (Shaw).

In eastern North America the range of the skunks extends from the high north well down into Florida, and the northern and southern extremes are very different and may be regarded as good subspecies. The principal external differences are that the northern skunk is a large, heavily built animal, with broad feet and a short tail (little more than half the length of head and body); while the southern skunk is a smaller, more lightly built animal, with slender feet and a long tail (about the length of the head and body).

There seems to be no name that applies to the southeastern skunk, and I therefore propose for it the name

Mephitis mephitica elongata subsp. nov., the southern skunk.

Geographical distribution.[1] Florida and southern Atlantic states north to about Connecticut.

Type No. 3051, coll. of E. A. and O. Bangs. ♂ young adult from Micco, Florida, March 5, 1895. Outram Bangs, collector. Total length 686 mm.; tail vertebrae 312 mm.; hind foot 72 mm.; ear from notch 34 mm. (measured in flesh by collector).

[1] Mr. Chapman in his Remarks on certain land mammals from Florida, with a list of the species known to occur in the state (Bull. Amer. mus. nat. hist., v. 6, 1894), speaks of the curious distribution of the two skunks found in Florida. I had the same experience this winter. I found Mephitis common at Micco, and Spilogale abundant at Oak Lodge on the East Peninsula just across the Indian River from Micco. At Oak Lodge Mephitis is unknown, and the same is true of Spilogale at Micco. This has been the experience of every one I have talked with who has known the two animals in Florida and is like the distribution of the turkey buzzard and black vulture throughout the south.

Description of the type of *Mephitis mephitica elongata* Bangs.

General characters. Size small, body slender, feet slender, tail long and tapering to a point, tipped with a pencil of white hairs; soles naked except the heel which is sparsely covered with hair.

Color. The usual white frontal stripe is narrow and does not reach the nuchal patch which is large. two broad white bands extend back from the nuchal patch over the sides of the back to and down the sides of the tail. The tail is mixed black and white above and below and tipped with a white pencil.

The rest of body, legs, head, and arms are black.

A very old ♂ adult topotype, No. 3052, coll. of E. A. and O. Bangs, March 10, 1895. Total length 719 mm.; tail vertebrae 321 mm.; hind foot 76 mm.; ear from notch 34 mm. (measurements taken in flesh by the collector, Outram Bangs); nearly black all over, having neither the usual white frontal stripe nor the white tip to the tail, the only white being the nuchal patch and two narrow bands extending back to about the middle of the sides. The tail is wholly black at the surface but many of the hairs are white for their basal half.

There seem to be no cranial characters of any importance by which the skulls of the two races of the eastern skunk can be separated, until we reach truly Hudsonian country. I have three skulls from Nova Scotia,— a young ♀ half grown,[1] and a very old adult ♂[2] from Digby, and the young adult ♂[3] described below from Annapolis. Nova Scotia, at least so far as its mammals are concerned, is Hudsonian.

These three skulls from Nova Scotia show one very striking difference from any other skulls that I have seen from the east. I have, however, examined none from farther north than Upton and Bucksport, Maine, both in the Canadian zone.

While it may be possible that the skulls from Nova Scotia represent a different form from anything on the main land, I do not think it probable and prefer to consider them as the Hudsonian extreme of the northern race.

The main difference is that the postpalatal notch in the Nova Scotian skulls ends in a plain, curved line with no sign of a median spine. In all the other eastern skulls before me, including

[1] 2023 coll. of E. A. and O. Bangs.
[2] 2022 coll. of E. A. and O. Bangs.
[3] 2249 coll. of E. A. and O. Bangs.

those from Maine, there is a large, blunt, median spine. In these Nova Scotian skulls also there is a deep, broad channel or groove between the basioccipital and the audital bulla. This groove begins in front of a bridge of bone directly in front of the foramen lacerum posterius and extends from there to the juncture of the sphenoid and basioccipital. This channel is present in both young and adults from Nova Scotia, and is present in a lesser degree in skulls from Maine, Massachusetts, and Connecticut.

It is also present, but very much reduced, in the type of *M. m. elongata* and in the topotype (No. 3052, coll. Bangs) above referred to. In three skulls of *M. m. elongata* from Blitches Ferry, Citrus Co., Fla. (Nos. 2282, 2283, and 2284, coll. Bangs), however, it is wholly absent. Two of these skulls are old adults and the third a young one nearly full grown, but with the sutures all open.

The southern skunk, *Mephitis mephitica elongata*, can be said to extend north about to Connecticut. Three adults in the collection of E. A. and O. Bangs from Liberty Hill, Conn., Nos. 1050, 2370, and 2416, though intermediate, are much nearer *M. m. elongata* than *M. mephitica*. In the same collection there is a large series from Wareham, Mass. Almost every individual in this series is a perfect intermediate between the two forms.

Description of *Mephitis mephitica* (Shaw).

No. 2249, coll. of E. A. and O. Bangs. ♂ young ad. from Annapolis, Nova Scotia, Dec. 1, 1894 (measured in flesh by O. Bangs). Total length 635 mm.; tail vertebrae 226 mm.; hind foot 78 mm.; ear from notch 34 mm.

General characters. Size large, body large, broad, and heavy, feet broad, soles naked except the heel which is sparsely covered with long hairs, tail short, tapering to a point, and tipped with a pencil of white hairs.

Color. A broad white frontal stripe extends to the nuchal patch which is of moderate size. Two white stripes extend back from the nuchal patch to the middle of the sides, where they disappear. Many of the hairs of the tail are white for their basal half, then black. Tail tipped with a long white pencil. The rest of the animal is black.

Geographical distribution. Hudsonian and Canadian zones of the east, south to about Massachusetts.

Just how far west the eastern skunks extend I am unable to say, but that they do not intergrade with the large-tailed western skunks I feel convinced. The western skunks form a separate

group, — very different in many particulars from the *Mephitis mephitica* group. The principal differences are the large bushy tail with a blunt brush-like end (never tipped with white as in the eastern species) around which the long white hairs of the sides of the tail fall, the heavy dentition, large, massive, elongated skull, and the much larger size of the animal. These skunks are also more uniform in coloration than the eastern ones and seem to have almost always the two white stripes extending from the nuchal patch right back to and down the sides of the tail enclosing a black central stripe all along the back.

MEASUREMENTS OF TWENTY-FOUR EASTERN SKUNKS.

Mephitis mephitica (Shaw).

No.	Locality.	Sex.	Age.	Total length.	Tail vertebrae.	Hind foot.	Ear from notch.
2249[1]	N. S., Annapolis.	♂	young ad.	635	226	78	34
2022[1]	N. S., Digby.	♂	old ad	682	171	83	33.5
2433[1]	Maine, Buckport.	♀	old ad.	544	169	62	30
2684[2]	Maine, Upton.	♂	old ad.	660	280	70	
2683[2]	" "	♂	old ad.	612	217	68	
2024[1]	N. S., Digby.	♂	young.	390	146	60	24.5
2023[1]	" "	♀	young.	439	179	65	28 5

Intermediate between *Mephitis mephitica* and *M. m. elongata.*[1]

No.	Locality.	Sex.	Age.	Total length.	Tail vertebrae.	Hind foot.	Ear from notch.
1705	Mass., Wareham.	♂	old ad.	599	200	68.5	26
1708	" "	♀	old ad.	548	231	54.5	26
1709	" "	♀	old ad.	623	248	64	28
1706	" "	♀	old ad.	595	251	61	33
798	" "	♀	old ad.	584	242	63	26
112	" "	♀	old ad.	569	228	62	28 5
1736	" "	♂	young ad.	580	241	69	30.5
1735	" "	♂	young ad.	561	226	67	27
1711	" "	♂	young.	336	137	45.5	23
1710	" "	♀	young.	329	128.5	45	22
1050	Conn., Liberty Hill.	♀	adult.	565	252	63	28
2416	" " "	♀	young ad.	564	253	60.5	28
2372	" " "	♂	old ad.	591	239	63	29

Mephitis mephitica elongata Bangs.

No.	Locality.	Sex.	Age.	Total length.	Tail vertebrae.	Hind foot.	Ear from notch.
3052[1]	Fla., Micco.	♂	old ad.	719	329	76	34
3051[1]	" "	♂	young ad.	686	312	72	34
2482[3]	" Blitches Ferry.	♂	young ad.	715	351	72	
2483[3]	" " "	♀	old ad.	673	330	70	

[1] Measured by O. Bangs.
[2] Measured by James Bernier.
[3] Measured by F. L. Small.

MEASUREMENTS OF SEVENTEEN SKULLS OF EASTERN SKUNKS.

No.	Locality.	Sex and age.	Basilar length of Hensel.	Occipitonasal length.	Greatest zygomatic breadth.	Greatest mastoid breadth.	Breadth across post-orbital processes.	Least interorbital breadth.	Distance from inferior lip of foramen magnum to postpalatal notch.	Palatal length.	Height of cranium from palate to point between postorbital processes.	Height of cranium from basisphenoid to parietal.	Greatest breadth of brain-case above or in front of inflated mastoids.	Greatest length of under jaw.
	Mephitis mephitica (Shaw).													
2249	N. S., Annapolis.	♂ yg. ad.	66.5	66	45	39	22	19.5	40	26.5	21	24	27	48.5
2022	N. S., Digby.	♂ old ad.	71	71	49.5	41	—	—	42	29	—	23	28.5	50
2433	Maine, Bucksport.	♀ old ad.	59.5	62	44	38	20	17	35.25	24.25	20.5	22	27	44
2683	Maine, Upton.	♂ old ad.	63	67.5	49	39	22.5	19.5	36	27	21	23	28	48
2684	" "	♂ old ad.	64.5	68	49.5	42.5	22	20	37	27.5	21	23	28	49
	Intermediate between *Mephitis mephitica* and *M. m. elongata*.													
1705	Mass., Wareham.	♂ old ad.	61	65	45	40	21.5	19	36	25	22	22	29	43
797	" "	♂ old ad.	60.5	63	45	37	21	19	36	24.5	20	22	27	43
1706	" "	♀ old ad.	56	62	42	35.5	20	17	32	24	20	21.5	27	42
1707	" "	♀ yg. ad.	55	62	41	35	20	17.5	32	23	20	21.5	28	40
2372	Conn., Liberty Hill.	♂ old ad.	58	60	43.5	37	20.5	19.5	35	23	19	21	28	43
2416	" " "	♀ yg. ad.	56	60	41	35	20	18.5	32	24	20.5	21	27	41
1050	" " "	♀ yg. ad.	55	60	40.5	34	20	19	31.5	23.5	20	20.5	27.5	41
	Mephitis mephitica elongata Bangs.													
3052	Fla., Micco.	♂ old ad.	64	70.5	48.5	40.5	23	20.5	36	28	21	23	28.5	49.5
3051	" "	♂ yg. ad.	61.5	65.25	46	39	21	19	33.5	28	20.5	21.5	27	47
2482	" Blitches Ferry.	♂ yg. ad.	59.5	64	45.5	37	21	19	34	25.5	22	22	27.5	44
2484	" " "	♀ old ad.	57.5	62	45.5	36	21.5	20	32.5	25	22	21.5	28	44
2483	" " "	♀ old ad.	56	63	—	37	20.5	19	31	25	21.5	22	28.5	42

Owing to lack of material I do not propose to discuss the relationship of the western skunks *inter se*, but one point is clear, that we must recognize Richardson's *Mephitis americana* var. *hudsonica* described in Fauna Boreali-Americana, Quadrupeds, p. 55–56. His description is fairly clear, and he gives one of the localities where the species is common as the "Clumps of wood which skirt the sandy plains of the Saskatchewan."

The skunk that must thus bear the name *Mephitis hudsonica* (Richardson) is the largest of all our skunks and has an extensive range in the northern prairies, extending as far east at least as Minnesota (Fort Snelling and Elk River).

DESCRIPTION OF A NEW MINK PUTORIUS (LUTREOLA) VULGIVAGUS SP. NOV., FROM THE BAYOU REGION OF LOUISIANA.

In the collection of mammals made by Mr. F. L. Small, at Burbridge, La., is a series of eleven mink, representing a species *Putorius* (*Lutreola*) *vulgivagus* very different from the *P. vison* of the northeast. This mink Mr. Small found abundantly in swamps, and along the numerous water-courses of that saturated country; and doubtless it has a wide range along the Gulf Coast, and perhaps well into the interior of the country. The great differences between it and *P. vison*, however, seem to be specific, and I doubt whether it passes into that species at any point.

I have never been able to see a Florida mink and I do not know of a single specimen in any collection, although it has been reported by Maynard and others who have collected in Florida. I hunted for it in vain along the Indian River and was unable to find any "signs," or get any word of its occurrence from the native hunters and trappers. Once or twice, I was told that "mink" were occasionally killed, but on close questioning these "mink" always turned out to be the Florida weasel (*Putorius peninsulae*). This I actually proved on one occasion — when a plume-hunter told me he had killed a "mink" up a live oak tree, about a year before, and had skinned it. The skin got rain-soaked and spoilt in a storm and he buried it.

When he found that I placed a commercial value on the remains, it acted as a stimulus to his memory and he exhumed what was left of it and brought it to me. The skull was left in the skin and was nearly perfect. The animal was Rhoads's *Putorius peninsulae.*

This confusion of the common names might mislead any investigator who went on hearsay evidence, but Mr. Maynard clearly states that he saw a mink at Blue Springs, and that the animal was very common on the coast near Cedar Keys. While it would be interesting to see Florida mink, I have no doubt that they are the same as the Louisiana animal. I am very sorry not to be able to map out the northern range of *P. vulgivagus* and the southern range of *P. vison* and show what relation they bear to each other, but there seems to be a total lack of specimens from the necessary localities.

I know that *P. vison* is common in the Alleghanies, as far south as Virginia and North Carolina, and there is a mink skin in the Museum of comparative zoology at Cambridge, labeled "Salt marshes of Carolina." It is an old skin with the skull inside, but it has every appearance of belonging to the species here described. Dr. Barton in Trans. Amer. philos. soc., vol. 6, p. 70, 1809, gave the name *Mustela winingus* to an animal supposed to occur at St. Louis on the Mississippi River. He gave no description, and his name is a pure *nomen nudum.* It came about in this way. Dr. John Watkins, in a letter to Dr. Barton, at the latter's request, sent him a list of mammals and trees occurring in that region, and in the list mentions "mink." Nothing more is said about the animal than this one word. When Dr. Barton published the letter he put an asterisk against the name "mink" and in the foot note says "*Mustela winingus* mihi. B. S. B." Of course Dr. Barton's name, whatever the animal may have been, has no standing in nomenclature.

Putorius vulgivagus seems to be an animal a little smaller than *P. vison*, from which it differs widely in cranial and dental characters and also in color. The eleven specimens of *P. vulgivagus* are very uniform in color, the only difference being a trifling one in the shade of brown, and the usual variation in the amount of white on the under parts, a variation shown by any

series of mink. No. 2752 has the white extending all along the under parts from the chin to the vent in a stripe of varying width, and the front feet are white.

No. 2758 has no white anywhere except a very small spot on each side of the lower jaw. Between these two extremes there is every degree of difference. The whole series was taken in January. At this season our northern mink (*P. vison*) has passed its prime. The finest and darkest furs are from animals killed between the middle of October and the middle of December, but even in midsummer the northern mink is darker and redder than *Putorius vulgivagus* is in January, and with a good series of the two species the difference in color is very apparent but almost impossible to describe. The general color is not so red and dark but has a look as if it had been brought down by the mixing in of clay color.

The fur is lustrous and thick, and although not of the beautiful chocolate-brown shades of the northern mink, is of a color very pleasing.

Some individuals in the series of *P. vulgivagus* are very old, No. 2752 being the oldest mink I ever examined.

I have always had difficulty in getting old examples of *P. vison* for the reason, I suppose, that they are caught off for fur before they attain a great age.

As it is important to compare skulls of the same age I have for this reason taken for the type a rather young adult of about the same age as most of the adults of *Putorius vison* in the collection of E. A. and O. Bangs.

The accompanying tables of measurements show *P. vulgivagus* to be very nearly the same size as *P. vison* but averaging a trifle smaller. On the other hand the skull of *P. vulgivagus* is larger than that of *P. vison*. Great care has been taken in picking the individuals of *P. vison* from which the measurements are made to have them as near the same age as the series of *P. vulgivagus*. For this reason I only give measurements of five skulls of each, as I am unable to match the very old examples of *P. vulgivagus* with skulls of *P. vison* of corresponding age. The five skulls of each agree in age in pairs in the two tables in the order in which they come.

Description of the type of *Putorius* (*Lutreola*) *vulgivagus* Bangs.[1]

Type No. 2751, coll. of E. A. and O. Bangs. ♂ adult, from Burbridge, La., Jan. 10, 1895. F. L. Small, collector. Total length 567 mm., tail vertebrae 173 mm., hind foot 71 mm. (measured in the flesh by collector).

General color. — A uniform rich light lustrous brown (of a color impossible to match by Ridgway's Nomenclature of colors, though perhaps a mixture of vandyke brown, burnt umber, and clay color would be nearer to it than any); the end of the tail is a few shades darker. The chin, a small spot on the throat, and a few hairs on the belly, between the legs, are white. The under fur is of the same color as the long hairs.

Cranial characters. — The skull of *Putorius vulgivagus* is very weasel-like in its general shape and appearance; the whole of the upper surface being well arched and rounded, not flattened and level and otter-like, as is the skull of *P. vison.* This difference is particularly noticeable in the frontal bones. The region between the postorbital processes is in *P. vison* almost level. In *P. vulgivagus* this region rounds up from the sides to the middle, following the general contour of the skull.

The skull of *P. vulgivagus* is also deeper than that of *P. vison.* The audital bullae of *P. vulgivagus* are larger, more inflated, and deeper than those of *P. vison.*

The skull of *P. vulgivagus* is considerably larger than that of *P. vison.*

The dentition is much heavier throughout, particularly the last upper molar which is half as large again as the corresponding tooth in *P. vison.* This tooth is also much less nipped in the middle than in *P. vison*, ending posteriorly in an almost straight line.

The minks constitute quite a well-marked group in the genus Putorius, and their large size, aquatic habits, different coloring, and the partial webbing of the feet are characters which, taken together, make it as well to retain Lutreola as a good subgenus of Putorius, but I must confess that I fail to find any characters of generic value, and therefore differ from most modern mammalogists who accord to Lutreola full generic rank.

[1] I have selected for the type an individual so old that the sutures are all closed and the bony crests beginning to develop and yet with the teeth unworn and perfect.

MEASUREMENTS OF TEN SPECIMENS OF *Putorius* (*Lutreola*) *vison* (BRISSON).[1]

No.	Locality.	Date.	Sex.	Age.	Total length.	Tail vertebrae.	Hind foot.	Ear from notch.
2021	N. S., Digby.	July 27, '94.	♂	yg.	561	173	61.5	25
242	Conn., Liberty Hill.	Feb. 14, '94.	♂	old ad.	594	203	58.5	22
1947	" " "	Oct. 25, '94.	♂	ad.	611.5	221	67.5	25.5
2428	N. S., Annapolis.	Jan. 1, '95.	♂	yg. ad.	520	179.5	60	25.5
2437	Me., Bucksport.	Jan. 24, '95.	♂	ad.	582	199	64	25
2434	" "	Jan. 16, '95.	♂	ad.	580	194	64.5	25
235	Mass., Wareham.	Apr. 10, '93.	♂	old ad.	581	190	69.5	23.5
2019	N. S., Digby.	July 26, '94.	♀	old ad.	497	143.5	50	20
2250	N. S., Annapolis.	Dec. 1, '94.	♀	ad.	499	170	56	23
234	Conn., Liberty Hill.	Mar. 6, '93.	♀	old ad.	541	174	53	21

MEASUREMENTS OF ELEVEN SPECIMENS OF *Putorius* (*Lutreola*) *vulgivagus* BANGS.[2]

No.	Locality.	Date.	Sex.	Age.	Total length.	Tail vertebrae.	oot.
2751	La., Burbridge.	Jan. 10, 1895.	♂	ad.	567	173	71
2752	" "	Jan. 21, 1895.	♂	old ad.	617	208	79
2753	" "	Jan. 23, 1895.	♂	ad.	507	157	69
2754	" "	Jan. 25, 1895.	♂	old ad.	573	192	70
2755	" "	Jan. 29, 1895.	♂	old ad.	612	187	73
2756	" "	Jan. 20, 1895.	♂	ad.	559	183	69
2757	" "	Jan. 21, 1895.	♂	old ad.	571	192	68
2758	" "	Jan. 24, 1895.	♂	ad.	546	189	66
2759	" "	Jan. 11, 1895.	♂	ad.	527	164	62
2760	" "	Jan. 14, 1895.	♂	ad.	552	179	70
2761	" "	Jan. 26, 1895.	♀	old ad.	478	159	58.5

[1] O. Bangs, collector.

[2] F. L. Small, collector.

Cranial Measurements of Five Skulls Each of *Putorius (Lutreola) vison* (Brisson) and *P. (L.) vulgivagus* Bangs.

	Putorius (Lutreola) vison.					Putorius (Lutreola) vulgivagus.				
						Burbridge, La.				
	Conn., Liberty Hill, 242 ♂ old ad.	Maine, Bucksport, 2434 ♂ ad.	Mass., Wareham, 235 ♂ old ad.	Conn., Liberty Hill, 1947 ♂ ad.	Nova Scotia, Digby. 2010 ♀ old ad.	2754 ♂ old ad.	2751 ♂ ad.	2755 ♂ old ad.	2760 ♂ ad.	2761 ♀ old ad.
Basilar length of Hensel.	57.4	56.8	58.2	58.6	51.4	61.2	60	62.2	59.4	51.2
Occipitonasal length.	57.2	56.4	56.4	58.6	51.6	59.8	61.2	61.4	60.2	51.4
Greatest zygomatic breadth.	38	37	38	37.2	32.8	38.6	37.2	40.4	37.8	33.2
Breadth across postorbital processes.	16.6	15.4	17.2	16.8	14.8	19	18.4	18.2	19.4	16
Height of cranium from palate to point between postorbital processes.	12.2	11.6	12.4	12.6	11.8	14.4	14.2	14.8	15.4	13.2
Height of cranium from basiosphenoid to parietal.	17	17.8	18.4	18.6	16.2	19.6	19.4	19	19.6	17.2
Greatest length of under jaw.	36.4	36.8	37.2	37.6	31.2	38.8	39.4	40.6	39.6	33.2
Height of coronoid process from angle.	14	13.4	13.2	13.2	12	14.2	14	14	14.2	12

DESCRIPTION OF A SUBSPECIES OF MUSKRAT, FIBER ZIBETHICUS RIVALICIUS SUBSP. NOV., FROM LOUISIANA.

The muskrat has long been known to occur in the lower Mississippi region and along the swampy coasts of the adjacent States of Alabama and Louisiana, but I know of no specimens from there having come into collections, until I sent Mr. F. L. Small, in Jan. 1895, to make a collection of mammals in this rather desirable section of the country.

He reported the muskrat as being very common all through the Bayou country and sent me in the early part of February three adults and three young from Burbridge, La. He kept on collecting at Burbridge, making a nice series of muskrats, and then shifted to another part of the State, taking the skins with him, where they were all destroyed by an unfortunate fire, which

left him without clothes or tools and destroyed the result of five weeks' hard collecting.

The six skins that I have, however, show the muskrat of this region to be a well-marked subspecies.

It is smaller than *Fiber zibethicus*, being about the size of *F. z. pallidus*, and is of a very different color from either, having a dull sooty appearance and lacking all the beauty and luster of northern specimens.

Description of the type of *Fiber zibethicus rivalicius* Bangs.

Type No. 2719, coll. of E. A. and O. Bangs. ♂ adult from Burbridge, La., Jan. 31, 1895. F. L. Small, collector. Total length 530 mm.; tail 222 mm.; hind foot 81 mm. (measured in the flesh by the collector).

Upper parts.[1] Outer hair from clove-brown to black, rather sparse and lusterless; under fur mouse-gray at base, shading to sepia at the ends.

Under parts. Outer hair sparse, of a color between vandyke and clove-brown; under fur mouse-gray at the base and hair brown at the tips. On the under side of the legs and arms the fur is very short and a dirty brownish white to the base. There is a spot in the middle of the sides where the under fur is silvery white to the base.

The feet, hands, and tail are black.

The skulls of this form do not seem to differ from the skulls of true *F. zibethicus* from the North Atlantic states and Canada, except in their smaller size.

Measurements of Five Adult Specimens of *Fiber zibethicus rivalicius* Bangs.

No.	Locality.	Date.	Sex.	Total length.	Tail vertebrae.	Hind foot.
2719	La., Burbridge.	Jan. 31, '95.	♂	530	222	81
2720	" "	Jan. 11, '95.	♀	516	206	71
2721	" "	Jan. 10, '95.	♂	517	228	79
2883	" Hackberry.	Apr. 15, '95.	♂	498	202	76
2884	" "	Apr. 15, '95.	♂	495	203	76

[1] Colors according to Ridgway's nomenclature.

THE LOUISIANA GRAY SQUIRREL, SCIURUS FULIGINOSUS BACHMAN.

In his monograph[1] of the genus Sciurus Dr. Bachman describes a squirrel from New Orleans, Louisiana, under the name *Sciurus fuliginosus*. All recent writers upon this genus have agreed in considering this as a synonym of *S. carolinensis*, but a series of thirteen fine skins I have just received, collected at Gibson, Louisiana, by Mr. F. L. Small, leads me to regard *S. fuliginosus* as a well-marked subspecies, which may stand as *Sciurus carolinensis fuliginosus* (Bachman), The Louisiana gray squirrel.

Sciurus fuliginosus Bachman, Trans. zool. soc. Lond., Aug., 1838.

Aud. and Bach., Quadrupeds of N. America, vol. 3, p. 240, pl. 149, f. 2, 1845.

Type locality, New Orleans, Louisiana.

Dr. Bachman's description was evidently taken from a very dark individual, rather darker than any in my series. He gives the tail as only 6 inches 9 lines long, and shorter than the head and body. This is undoubtedly an error and probably arose from the tail of Dr. Bachman's specimens having been broken off, as is very frequently the case with all squirrels. I remember once shooting four or five northern gray squirrels in succession, all with the end of their tails gone.

The chief differences between this subspecies and *S. carolinensis* from Florida and Georgia are, that the Louisiana gray squirrel is a larger animal, almost as big as the northern gray squirrel, *S. carolinensis pennsylvanicus* (Ord), with large broad hind feet. The color of the upper parts is darker and richer with much black in the upper surface of the tail.

The under parts are never pure white, as are the under parts of *S. carolinensis*, and the line of demarcation between the colors of the under and upper parts is never distinct, and this is especially true of the under surface of the legs and arms.

The under parts of *S. fuliginosus*, as shown by my series, vary from a strong buffy ferruginous in No. 2840 to a dirty grayish white in No. 2833, the thirteen skins showing every stage between these two extremes.

[1] Trans. zool. soc. Lond., Aug., 1838.

No. 2840 is a very beautiful squirrel and probably nearer Bachman's type in color than any I have. The whole upper parts are deep yellowish ferruginous varied with black, and the under parts, except the chin and throat, which are dark yellowish gray, are bright buffy ferruginous. The tail is very dark and fringed on the outer edges with white-tipped hairs.

In all the skins in my series the upper surface of the feet and hands is much darker than in *S. carolinensis*. They all have very conspicuous woolly tufts at the back of the ears; in the examples with ferruginous under parts these ear-tufts are pale ferruginous, in the one with gray under parts they are grayish white. The ear-tufts often project a little distance above the top of the ear. I have never seen a specimen of *S. carolinensis* from Georgia or Florida in which the ear-tufts were at all conspicuous, and generally, even when the animals are in their fullest coat, the ears are almost naked.

Gmelin gave the name *Sciurus carolinensis* to the gray squirrel of the Carolina coast, which is really intermediate between the northern and the Floridan forms, and we are therefore met with the awkward question, shall we recognize three races, one of which is intermediate, or shall we use Gmelin's name for the southern extreme? I have adopted the latter course, and thus call the Florida gray squirrel, *Sciurus carolinensis* Gmelin.

The accompanying lists of measurements give a very good idea of the difference in size between the Louisiana, the southern, and the northern gray squirrels. They have been carefully taken from fully adult and accurately measured specimens. All the measurements were taken in the flesh by reliable collectors.

MEASUREMENTS OF TEN *Sciurus carolinensis pennsylvanicus* (ORD).

No.	Locality.	Date.	Sex.	Total length.	Tail vertebrae.	Hind foot.	Ear from notch.
1048[1]	N. C., Statesville.	Feb. 22, '94.	♂	471	213	61	33
1715[2]	Mass., Wareham.	June 15, '94.	♀	529	254	70	38
1038[2]	" West Tisbury.	Feb. 4, '93.	♂	440	208	63.5	29
1039[2]	" " "	Feb. 4, '93.	♀	476	212	63.5	29
1042[2]	Conn., Liberty Hill.	Apr. 22, '94.	♀	483	223	64	33.5
1043[2]	" " "	Apr. 22, '94.	♂	511.5	231	71.5	36.5
1946[2]	" " "	Oct. 24, '94.	♂	526	243	74	35
1040[2]	" " "	Mar. 18, '93.	♀	517	245	71	29
1041[2]	" " "	Mar. 18, '93.	♀	490	211	78	29
1787[3]	Ont., Mt. Forest.	Sept. 18, '94.	♂	595	242	74	

MEASUREMENTS OF TEN *Sciurus carolinensis* GMEL. (THE FLORIDA EXTREME.)

No.	Locality.	Date.	Sex.	Total length.	Tail vertebrae.	Hind foot.	Ear from notch.
3406[4]	Fla., Oak Lodge.	Feb. 1, '95.	♀	414	192	57	30
2251[5]	" Citronelle.	Apr. 12, '94.	♀	442	210	62	
2252[5]	" "	Apr. 12, '94.	♀	415	200	60	
2480[5]	" Blitches Ferry.	Sept. 11, '94.	♀	420	209	61	
2470[5]	" " "	Oct. 3, '94.	♂	416	190	62	
2467[5]	" " "	Sept. 4, '94.	♂	416	202	60	
2474[5]	" " "	Aug. 30, '94.	♂	408	190	57	
2466[5]	" " "	Sept. 16, '94.	♂	422	198	60	
2476[5]	" " "	Sept. 14, '94.	♂	441	216	60	
2479[5]	" " "	Sept. 14, '94.	♂	446	213	64	

[1] At a high altitude and perfectly typical of the northern subspecies. O. Bangs, collector.

[2] O. Bangs, collector.

[3] Black; this phase is commoner than the gray phase at this locality. Allan C. Brooks, collector.

[4] O. Bangs, collector.

[5] F. L. Small, collector.

MEASUREMENTS OF THIRTEEN *Sciurus carolinensis fuliginosus* (BACHMAN).[1]

No.	Locality.	Date.	Sex.	Total length.	Tail vertebrae.	Hind foot.
2840	La., Gibson.	Mar. 24, '95.	♀	463	206	66
2841	" "	Apr. 5, '95.	♂	455	212	68
2835	" "	Apr. 3, '95.	♀	460	212	62
2843	" "	Mar. 24, '95.	♀	459	223	64
2836	" "	Apr. 9, '95.	♂	484	227	66
2837	" "	Mar. 23, '95.	♂	459	250	68
2838	" "	Apr. 10, '95.	♂	451	204	64
2839	" "	Apr. 5, '95.	♂	448	205	64
2842	" "	Mar. 28, '95.	♂	467	216	68
2833	" "	Mar. 23, '95.	♂	479	220	70
2834	" "	Mar. 23, '95.	♀	478	216	71
2844	" "	Apr. 10, '95.	♀	448	203	64
2845	" "	Apr. 7, '95.	♀	466	213	67

CERRO VIEJO AND ITS VOLCANIC CONES.

BY J. CRAWFORD.

This noted mountain and landmark near the Pacific Ocean in western Nicaragua extends N. N. W. and S. S. E., its most western group of four volcanic cones being twenty-one miles distant from and 30° 38′ east of north of the Port of Corinto, and its eastern termination, a group of three cones of ejectamenta, sixteen miles northwest of the western margin of Lake Holotlan (Managua) at the foot of the volcano Momotombito. Its approximate dimensions are: base level length of its longitudinal axis, thirty miles; the distance south from its long axis to the margin of the lava flow, about twelve miles; thence south to the coast range of Cerros, eight miles; and from that range, east of south to the Pacific Ocean, three miles. North from the central long axis to the termination of extruded lava flow is eight miles; and the Cerro is there bounded by a tide-water estuary known as Estera Real which extends east from the Gulf of Fonseca for

[1] F. L. Small, collector.

seventy miles, on the north side of the Cerro. The altitude above sea-level of the ridges or Cimas del Cerro that connect the cones and craters varies from 2,000 to 4,800 feet, and that of the cones, of which Viejo is the highest, from 2,500 to 5,674 feet.[1]

Proceeding from west to east the names of the craters and cones on this mountain range are Chonco, Obraje, San Lorenzo, Viejo, Uval, Santa Maria, San Pedro, and Telica, and they are all connected by a high ridge. On the east the Cerro is connected, by a low ridge seven miles long, with the large oval-shaped volcanic mountain and cone Telas, and on the southeast, by another low intumescent ridge of about the same length, with the extensive mountainous masses of volcanic ejectamenta that border the northwestern part of Lake Holotlan (Managua) and support the large volcanic cone Momotombo, whose crater rim is over 6,480 feet above the Pacific Ocean.

The cones Santa Maria and Uval are still emitting aqueous vapors in small but continuous clouds from numerous mud springs near their craters.

The depth and dimensions of the grottoes or caverns or cauldrons under the Cerro that contain hydrothermal vapors[2] are approximately as follows: from the superior inner surface of the cavern up to the plane of the valley on which the Cerro is situated, or to about the level of the Pacific Ocean, is about 16,700 feet; from floor to top of the caverns, usually about 5,500 feet; from floor of cavern up to sea-level, about 21,500 feet; from floor of cavern to apex of the cone Viejo, about 27,760 feet.

The Cerro is composed of hydrothermal and igneous, excavated and extruded minerals chemically and mechanically combined, varying in size from the finest powder produced by attrition or strong pneumatic forces to large fragments of rocks with rounded angles and edges, and in structural features from light and porous, as scoriae, pumice, and Pele's-hair, to dense and heavy doleryte and basalt; excepting a ridge about nine miles long extending from Viejo to Uval, which is composed of sedimentary

[1] These measurements were carefully and accurately made for the author in 1891, by Lieut. W. B. Fletcher, of the U. S. Navy. Lieut. Fletcher is a constant student, especially of sea-margin currents and formations.

[2] For the facts in reference to the existence of these caverns and the authors' method of estimating their dimensions, see the end of this paper.

materials interstratified with submarine volcanic extrusions and also with subaerial volcanic ejectamenta. This ridge has been elevated to far above its present altitude (from 3,500 to 4,800 feet) by forces from beneath the strata assisted by lateral pressure from the S. S. W., *i. e.* from the Pacific Ocean, which have caused foldings and plications toward the N. N. E. It has deep ravines eroded in its southwestern side, and the rugosities of its general surface show long continued, severe, and active erosion which has exposed at many places its dual formation and structure. Two features that but seldom occur at such high altitudes in ridges of principally volcanic ejectamenta are here to be observed: (1) At an altitude of over 4,000 feet above sea level there is a large tilted stratum of arenaceous and plastic clays of irregular shape, more than three miles in length and with a thickness of from 10 to over 100 feet. This stratum extends from near the top of the ridge down its southern side for from 600 to 3,000 feet at an angle of about 9° 28′, and is covered by hard lavas and by peperino to depths varying from 10 to 300 feet. At three places it is exposed to view, on the sides of ravines in exposures about 1,500 feet long and of varying thickness. (2) Springs of cool water flow on this stratum to the surface of the Cerro and form a small creek, about 18 feet wide, and from 2 to 2½ inches deep, which runs over an exposed part of the stratum for about 1,500 feet to its termination, and then the water disappears into the porous ejectamenta. This stream has above it only a small catchment or hydrographic area, not sufficient to replace the water it loses by evaporation in its course, and it is evident that this large flow of water has percolated through the loosely compacted strata superimposed on the clay, or circulated through subterranean fissures for over four miles from numerous mud springs found active on the northeast side near the apex of the cone Uval. Outside of or beyond the ravine in which the creek flows, wherever the surface of ejectamenta has been denuded down to within 50 feet of the clay, the location of the clay and water in this side of the ridge is easily determined by the groves of large tall evergreen trees, such as nioperos, cedros ojoches, mahogany, etc., and also by the areas on which the coffee tree (*Cafe arabica*) flourishes.

Another stratum of arenaceous clay is exposed on the southern side of this ridge at an altitude of about 4,400 feet, near the crater in the cone Uval. A small stream of water percolates also from this bed of clay, but soon disappears through evaporation. Two other deposits of arenaceous clays were discovered on the southern side of the ridge at an altitude of about 2,000 feet, each interstratified with various kinds of semi-devitrified granopyric, pilotaxitic, and other kinds of lava. On the southern side of the ridge no sedimentary deposits were discovered in the fissures and ravines. There the volcanic extrusions were found to be basic in kind and increasing in percentage of iron and other metallic oxides toward the upper surface of the ridge. At a few places, however, near or at the floor of very deeply eroded ravines or at depths in fissures, the lava was composed principally of andesite, trachytes, and rhyolites.

The foundation stratum on which Cerro Viejo stands is sandstone interstratified with slate and magnesian limestone; the latter containing masses of hematite and magnetite, weighing from a few ounces to over a hundred pounds each, and cementing a large percentage of quartz sands.[1]

More than a hundred large springs of water flow from the northeastern, southern, and northwestern base of the mountain. They are generally in groups, and range in temperature from 70° to 100° C., many of them being of sufficient volume to form creeks from 20 to 40 feet wide and from 2 to 12 inches deep. Some of these springs have peculiarities worthy of special note, as the following descriptions of a few of them will show.

Agua caliente del San Pedro, covering a depressed area of about 400 yards diameter, contains numerous springs of boiling or hot water. It is located at the northern base of the volcanic cone San Pedro, and has differently mineralized subgroups, from some of which halcite crystalizes; from another subgroup silicates are deposited, from another sulphides, and from another travertine. The water is too hot to permit excavations down to the

[1] This stratum of magnesian limestone and sandstone is exposed for about fifty miles at various places near the Pacific Ocean, commencing a few miles south of Cerro Viejo. It has been eroded deeply, leaving at many places on the surface of the magnesian limestone hundreds of tons of hematite mixed with quartz sands and hardened; and for about 20 miles north of the Cerro it outcrops or is exposed by erosion at several places. It is of Paleozoic age, and on the south side of the Cerro is bisected for its entire length by a horizontal columnar dike about 12 feet wide.

fissures from which these various springs flow, but it is evident from the composition of the waters that they flow from different directions through fissures that converge to this depression. This opinion is confirmed by the following facts: (1) Between the subgroup charged with bicarbonates and the base of the cone Obraje, where large springs depositing travertine are found, is a depression from the floor of which bicarbonated waters bubble up in small quantities, which on cooling deposit travertine; (2) Between another subgroup of springs, which are impregnated with iron in solution, and the cone Uval, where iron oxides are exposed abundantly, there is a deep depression from the floor of which waters that are nearly saturated with iron exude in small quantities. The sources of the springs from which halcite crystalizes on cooling and those from which silicates are deposited on cooling were not satisfactorily discovered. These springs together form a creek of hot water about 7 miles long, which flows west into the tide-water estuary, Estera real.

Mud springs.— 1. At the eastern termination of Cerro Viejo, and at an altitude of 2,500 feet above the ocean, the apex of the volcanic cone Santa Maria is nearly encircled by a wide belt of mud springs. Their orifice is from 3 inches to 4 feet in diameter, and they have built up around themselves walls of pyroxene mud from 1 to 3 feet high that have become semi-hardened. The boiling mud oscillates up and down, but seldom rises to the rim of its surrounding wall of mud. The ground or space between these springs sustained, wherever tested, the weight of a man and horse, but sank perceptibly, returning after a few vibrations to its normal level when relieved of the pressure. Within a few feet of these springs, however, both above and below them, the Cerro is formed of inelastic lavas. All these mud springs appear to flow from a fissure of nearly circular form, over a hundred feet wide, and nearly surrounding the crater at the apex of the cone. 2. At an elevation of about 4,400 feet on the northeast side of the cone Uval, near its apex, there are numerous mud springs similar in general features to those on Santa Maria above described, but the walls deposited by the waters overarch and nearly conceal the springs. The rise and fall of the hot mud in these springs is periodic and uniform, there being a complete oscillation every two hours.

At the southern base of the cone Santa Clara are several large springs of water whose streams unite near the exposed ends of the fissures and interstratum spaces from which they flow, and form the Rio Que-sal-qua-que which disembogues into the tide-water estuary Paso Cabillo near the Port of Corinto.[1] A much larger quantity of water from these springs percolates through the strata and small fissures for a distance of over 7 miles, and then pours out over the surface of hard lavas of rhyolite, phonolite, and trachyte, forming the Rio Chiquito which flows through the eastern and southern parts of the City of Léon, and is far more than sufficient to supply the needs of the 60,000 inhabitants of that city and their more numerous domestic animals. Thence it flows into the Paso Cabillo near the mouth of the Que-sal-qua-que.

From the large springs issuing from the base of Santa Clara west to the southern foot of the group of four cones on the western end of Cerro Viejo is a distance of about twenty-eight miles, and in this interval more than fifty large springs of water rush out from between strata or from fissures that open at the extreme southern base of the Cerro, and each of them forms a small creek that finally discharges its silt, sand, and water into the Paso Cabillo. Even in the annual "dry season" these waters so fully supply the 144 square miles of the southeastern part of the valley of Chinandega as to enable its fertile volcanic soil to support large groves of evergreen trees and to produce annually under cultivation large crops of cacao (*Theobroma*), plantains (*Musa paradisiaca*), bananas (*Musa sapientum*), mangoes (*Mangiferea*), indigo (*Indigoferea*), sapota (*Sapotes achras*), anatto (*Bixa orellana*), corn, sugar-cane, rice, beans, oranges, lemons, limes, figs, grasses, etc., etc.[2]

[1] The estuary Paso Cabillo separates the island of Corinto from the main land. Its southern termination is the Port of Corinto, and its northern at the east of the island of Ascedadores in Nicaragua.

[2] Numerous excavations from 75 to 150 feet deep to the hard trap rock rapidly fill with water from 3 to 6 feet in depth. These wells, whose waters are for the most part warm, give evidence of the great quantity of high-tension, aqueous vapors that are continually forming in the caverns and are condensed into water on their passage from the caverns to the surface of the earth. There is not rainfall enough during the dry season to account for all the moisture, although it is true that this valley does not suffer from the drying effects of the currents from Bering Sea, since they are deflected southward at lat. 22 N. and long. 95 W. from Greenwich, at a point of land more than a hundred miles to the west of this valley.

About 3 miles southwest of the foot of San Lorenzo, the Chinandega River, a stream of warm water over 20 feet wide and 2 inches deep at its origin, issues from between horizontal strata of lava. It rapidly increases in volume for the first 2 miles of its length, and after flowing for a distance of about 25 miles in a tortuous course, empties into the estuary of Ascedadores, near the island of that name.

Three miles north of the head of the Chinandega River, at the western termination of Cerro Viejo, there is a group of large springs whose waters unite and form the Rio Viejo, a larger river than the Chinandega. About 5 miles farther north is another group of large springs which unite within 200 feet of their outpour from fissures and form the Rio Atoya, a river about twice the size of the Viejo. These two rivers flow nearly parallel and discharge their water, sand, and silt into the Ascedadores. The caverns whence the waters of these three rivers are condensed are evidently the same; they are similarly but slightly mineralized, and their heads are only three or four miles distant from the western termination of the group of cones at the western end of Cerro Viejo.

About 6 miles north of the group of springs that form the Rio Atoya and at about the same distance northwest of the base of the massive cone of rock materials called Obraje, are several large springs about 80° C. which are nearly saturated with bicarbonates, principally of calcium. All these springs are similarly mineralized, and are evidently from the same underground conduit, and, most probably, from the caverns or grottoes beneath the cone Obraje. They at once unite and form a shallow creek from 50 to 60 yards wide, which occasionally from excessive outpourings overflows the low wide valley on each side. These waters on cooling deposit calcium carbonate, forming large masses of travertine and onyx, while the rocks, leaves, and all detached vegetation over which they flow are encrusted, and accurate and beautiful casts and moulds are thus made. The waters evidently pass in fissures through the strata of magnesian limestone of Paleozoic era referred to above; or they flow in fissures through some bed of limestone rock or large deposit of shells or coral. The travertine and onyx are often in continuous deposits

to a depth of 25 feet from the surface of the creek, and are found in nearly connected deposits for a distance of about 4 miles northwest to the margin of the Estera Real. The depth of these deposits beneath the present surface of the earth is not known, but it is believed to exceed 200 feet. Their deposition has evidently continued through more than one of the epochs of the Pleistocene period, because some fragments of travertine moulds of leaves, etc., similar to those found near these springs, have been found in a ravine several miles north of Estera Real, in clastic deposits that were interstratified with ejectamenta, and have been exposed at depths of over 200 feet from the present surface of the earth. The interstratification referred to is beneath several others, and is associated with geological evidences of having been deposited in the early part of the Pleistocene. The fissure from which these springs, which are called Ojo de Agua, issue must incline downwards at an angle of 40° in order to avoid in its extension to the cavern beneath Obraje the deep Lake Lagunita which is between the springs and Obraje.

Six miles northeast of the Ojo de Agua springs and about 6 miles from the north foot of Obraje, is another group of large springs whose waters are charged with $CaCo_3$, and which also deposit large quantities of travertine, and whose tufaceous encrustations, travertine substitutions, and deposits of onyx are similar to the depositions from the waters of Ojo de Agua. The deposits from these two groups of springs commingle in an area of about 16 square miles; their waters have the same temperature, 80° C., and are most probably from the same source and pass through the same strata. Both creeks discharge into Estera Real, about four miles north of the springs. Large quantities of diatomaceous ooze and algae are found near the springs and in the creeks. A noticeable effect of these waters on the soil saturated by them is the favorable condition produced for the vigorous growth of some varieties of lactiferous trees of the fig family, especially of matapalas, a species of Ficus, a tree with many intertwining and inosculating aerial roots that descend from 20 to 40 feet from the large branches to the earth where they develop subterranean roots. The aerial roots often grow to over 12 inches in diameter, and, as does also the main body of the tree, yield by tapping a good quality of elastic rubber (*caoutchouc*).

The different salts with which several of the springs are impregnated indicate that their waters pass through separately and differently mineralized formations on their way from beneath the Cerro to the surface of the earth; and the very large quantity of water that flows continuously even in the dryest season (which lasts several months of each year) gives strong evidence that these waters are aqueous vapors condensed and usually differently mineralized in their passage from extensive caverns or grottoes deeply excavated beneath the Cerro, and consequently that these caverns are full of high tension aqueous vapors.

Depressions of land or sunken areas.— Between the calcareous springs above mentioned and the foot of the cones Obraje and San Lorenzo are five sunken areas, four of which are from 80 to 200 feet wide, from 400 to 1,000 feet long, and from 150 to 200 feet deep; their floors are inclined downward toward the base of the cones. These depressed areas are not craters of volcanoes, but most probably are local subsidences of the hard rocks and lavas toward the caverns beneath the Cerro. The fifth depressed area is about 1,800 feet long, 500 feet wide, and contains a lake (Laguna Celinde) of potable water that is over 300 feet deep (its depth has not been ascertained). This lake has an ebb and flow movement every two hours (about), and appears to increase but little by rains and decrease very little by evaporation, and to be connected with or influenced by the aqueous vapors in the cauldrons beneath the Cerro. The rocky western walls of this depression have numerous sharp, projecting fragments, and the lamination is contorted, indicating twisting movements during a rapid severance of the rocks as a part of them descended to greater depths.

On the southern side of Cerro Viejo are the four large depressed areas described below, whose floors incline downwards beneath the Cerro; as if the rocky materials that once occupied and filled these depressions had descended into some previously excavated cavern.

1. Hojo del Padro, near the base of the cone Uval, is about 300 feet deep and covers about twelve acres of ground; its floor is covered with "granier nois" and lapilli, and it sustains a constant growth of grasses and small trees, although water is found

only at a depth of over 100 feet beneath the floor, excepting during the rainy season of each year.

2. Hojo de Sapote is near the southern base of the cone Viejo. It covers about twenty acres of land, and its floor is about 400 feet below the surface of the earth at that part of the Cerro. An excavation to about 90 feet beneath its floor opened into a fissure from which carbonic oxide (CO_2) escaped.

3. Hojo de los Canos, south of the base of the cone Santa Maria and near the eastern extremity of Cerro Viejo, has a depth of about 300 feet, and includes an area of about twenty-five acres. Grasses and several varieties of trees flourish on its floor.

4. In the same division of the Cerro there is another depressed area nearly as large and deep as Hojo de los Canos.

The distinct inclination of the floors of these sunken areas beneath the Cerro is a feature worthy of note, and indicates that beneath the Cerro are large and deep caverns or grottoes that were excavated by hydrothermal and other igneous forces.

The volcanic extrusions of which the Cerro is in large part composed appear to have been expelled during each time of volcanic activity in nearly regular series as to texture of ejectamenta, and the series appear to have followed each other in order of composition usually from the more acid to the more basic. So far as observations on the surface and in deep ravines in the ridges and cones indicate, the extrusions in the Cerro from its base level (*i. e.*, the present surface of the valley from which it rises) up to about one half its height are composed of rhyolites, trachytes, phonolites, pumice, and other acid lavas in greatest proportion. In cooling, these have assumed various textures, as hyaline and scoriaceous-crystalline, and are intermixed with trachy-dolerites, hardened-amorphous silicates, Infusoriae, and fragments of syenitic and granitic igneous rocks. The cones and upper parts of the ridges are composed largely of hardened aphanitic and hyaline lavas and ejectamenta of peperino, while masses and fragments of dolerite, basalts, and other basic rocks are exposed in large quantities at their bases, and also form a small ridge near the foot of the Cerro whither they have been sent by the jarring of earthquakes and volcanic disturbances or have been transported in floods of mud (aluvions del barro) during heavy and long con-

tinued rainfalls. Devitrefication and alteration of minerals and masses of lava into palagonite and laterite, and also metasomatic changes, are found at several places both north and south of the Cerro.

The early genetic history of the Cerro, studied in connection and correlation with the geological features and structure of the province or part of the Pacific coast in Nicaragua, presents numerous points of much interest, especially in regard to the volcanic activity; *e. g.* (1) The deposits of Jurassic and Cretaceous coals found a few leagues north of the Cerro, and formed on magnesian limestones of the Paleozoic era, with thin strata of sand and clay intervening, and covered by several thickly laminated sheets of volcanic extrusions deposited during a subestuarian activity; some of this coal has been softened by heat, and, while in that condition, was sprinkled with sands and cinders. (2) Exposures caused by upheavals and faulting disclose many interstratifications of clastic deposits and volcanic materials, which were made during submarine activities since the Mesozoic era, and which continue through the valley in which the Cerro is located. (3) At two places it was noticed that the continuity of the volcanic submarine strata and their color and mineralization were quite different from those of other parts of the deposit in the same zone. This peculiar deposit is a hard arenaceous clay, its color, through the presence of an aluminate of gold (Au Al), varying from pink to purple. It appears that the volcanic conditions of greatly heated chemical vapors caused the auriferous clays and quartz composing the gangue of some auriferous fissure or "lode" to form, in part, a chemical union of aurum and aluminum, an ore of gold. (4) For about a hundred miles from the shore line of the Pacific Ocean near Cerro Viejo west into the Ocean, there is a depressed area, still sinking, which extends south along the western coast of Nicaragua and Costa Rica, from about lat. 14° N. to lat. 10° 30′ N. This depression is, most probably, coeval with the beginning of Cerro Viejo, Coseguina, and Momotombo, and is filling up as rapidly as it descends with disintegrated volcanic ejectamenta transported into it by rain floods from southern Salvador and Honduras and western Nicaragua and Costa Rica. It is quite probable that the heat, which, if allowed to

accumulate and remain in the cauldrons beneath Cerro Viejo where it originates, would cause frequent volcanic outbursts from the craters of the Cerro, is removed by convection and other processes into this extensive submarine accumulating deposit of sedimentary materials, and thus the volcanoes are relieved from activity. The shore line of this subsiding area has lowered nearly two feet since the early part of 1881, as measured by comparing the present altitude of a railway on that coast with its altitude when first constructed in 1881. (5) Undulatory movements of the land surface between the ocean and the Cerro have been noticed on several occasions, the entire oscillation of depression and re-elevation being at one time nearly 20 inches.

The evidences noted by the author of the existence of extensive, deeply-located, deep caverns beneath the volcanic belt in western Nicaragua, and the methods used to ascertain or rather estimate their dimensions and depth beneath the earth's surface, and the evidence of the origin in them of a large number of the earthquakes felt in that part of Nicaragua, will be considered in another paper. It would be quite difficult to account satisfactorily for the very large and continuous flow of waters from beneath Cerro Viejo. Otherwise than that, these waters are hydrothermal vapors developed in caverns beneath the Cerro and are condensed into water while on their way to the earth's surface from the highly heated subvolcanic cauldrons.

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The names of genera and species described as new are italicized.

ERRATA.

Page 163: the last line should be transferred to top of p. 162.
Page 497, line 21: for April 2 read April 3.

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